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JOURNAL OF DAIRY SCIENCE

OFFICIAL ORGAN OF THE
AMERICAN DAIRY SCIENCE ASSOCIATION

Contents

Influence of Two Planes of Feeding and Care upon Milk Production. T. E. WOODWARD 283
A Graphical Method of Proportioning and Standardizing Ice Cream Mixes. WALTER V. PRICE 292
On the Calculation of the Freezing Point of Ice-Cream Mixes and of the Quantities of Ice Separated during the Freezing Process. ALAN LEIGHTON 300
Soft Cheese Investigations. JULIUS CHARLES MARQUARDT 309
Some Observations on the Freezing Points of Various Cheeses. PAUL D. WATSON AND ALAN LEIGHTON 331
The Effect of Heat Treatment of Skim Milk upon the Baking Quality of the Evaporated and Dried Products. GEORGE R. GREENBANK, MABEL C. STEINBARGER, E. F. DEITHER AND GEORGE R. HOLM 335
The Rate of Acid Production in Heated Milk. F. O. WHITTIER AND ANNE G. BENTON 343
Inheritance of Butterfat Percentage in Jersey Cows. LYNN COPELAND 344
Some Observations on the Freezing Point of Cream and Its Use in Detecting Added Water. F. J. DOAN 353
Effect of Temperature on the Viscosity of Skimmilk. RANDALL WHITAKER, J. M. SHERMAN, AND PAUL FRANCIS SHARP 361

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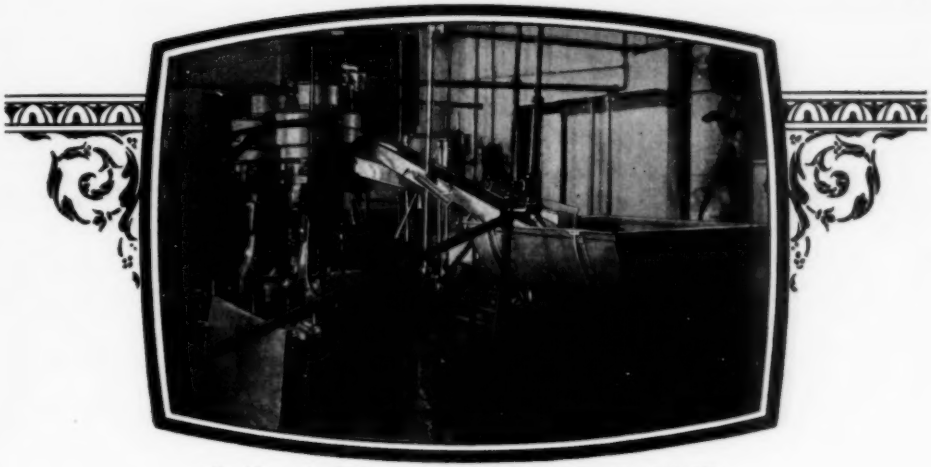

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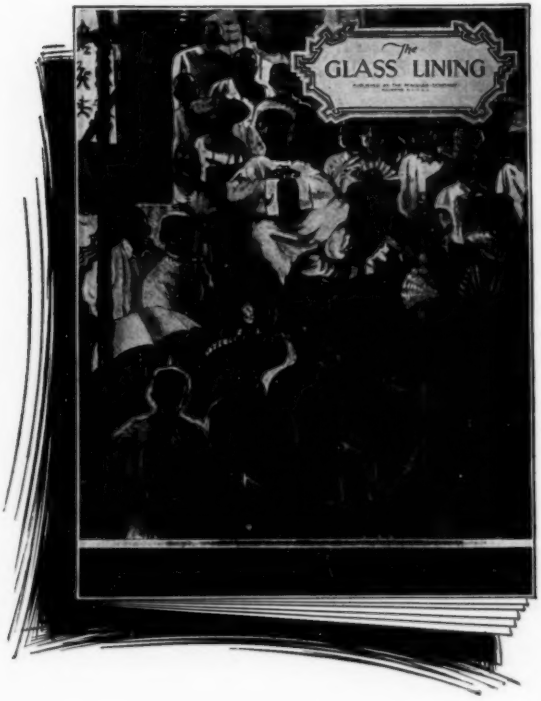

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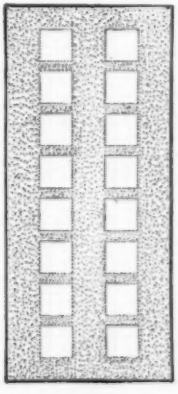

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INFLUENCE OF TWO PLANES OF FEEDING AND CARE UPON MILK PRODUCTION*

T. E. WOODWARD

Bureau of Dairy Industry, United States Department of Agriculture, Beltsville, Md.

When testing for the Advanced Registry and the Register of Merit was started at the dairy experiment station of the Bureau of Dairy Industry a number of years ago, it was noticed that the cows when on test produced a great deal more milk than they did when milked and fed only twice a day and otherwise managed in much the same way that any good dairyman might take care of his herd. This led to some specific experiments with certain animals to ascertain how much increase might be expected by keeping them under test conditions, and also to the tabulation of data regarding other animals which in the ordinary course of events were found to have made yearly records under each of the two conditions called for convenience "test" and "herd."

In brief, the test conditions were as follows: Keeping the cows in boxstalls, milking three times a day, feeding three times a day, feeding a large quantity of alfalfa hay and a small quantity of silage, feeding somewhat in excess of requirements as computed from the common feeding standards, feeding beet pulp, breeding to freshen about fifteen months from previous calving, and allowing no pasture. The herd conditions in the main were as follows: Keeping the cows in stanchions, milking twice a day, feeding twice a day, feeding smaller quantities of hay and a generous amount of silage, feeding only slightly more nutrients than called for by the standards, feeding no beet pulp, breeding to freshen about twelve months from previous calving, and allowing pasture to some of the cows.

Twenty-two cows included in this study have completed records under both conditions. One has made four records, six have made three records, while each of the remainder have made

* Received for publication March 7, 1927.

TABLE 1

Comparison of herd and test conditions

COW	BREED	AGE AT BEGINNING OF RECORD		HERD OR TEST CONDITIONS	LENGTH OF RECORD	DAYS PREGNANT	AVERAGE WEIGHT	GAIN IN WEIGHT	GRAIN	DRIED BEET PULP	HAY	SILAGE	PASTURE	ACTUAL PRODUCTION		PRODUCTION CORRECTED FOR AGE		INCREASE			
														Milk	Fat	Milk	Fat	Milk	Fat	Milk	Fat
		yrs.	mos.		days		pounds	pounds	pounds	pounds	pounds	pounds	days	pounds	pounds	pounds	pounds	pounds	pounds	per cent	per cent
50	Gr. Hol.	4	2	Herd	365	105	1,067	4	3,207	0	1,977	10,625	69	9,323.7	345.93	11,099.6	411.82	3,821.7	156.01	33.5	36.5
		5	9	Test	365	0	1,157	192	4,980	2,190	5,824	7,249	0	14,515.1	555.65	15,240.9	583.43				
		7	11	Herd	365	0	1,135	12	6,954.7	0	3,652	12,535.5	0	11,727.2	442.59	11,738.9	443.03				
51	Gr. Hol.	5	6	Test	320	11	1,163	109	4,201	1,716	5,176	6,227	0	16,562.2	633.80	17,555.9	671.83	5,604.0	226.08	46.9	50.7
		7	2	Herd	320	226	1,207	58	4,462.3	0	2,618	9,937.3	0	11,808.5	440.40	11,951.9	445.75				
64	Gr. Hol.	5	7	Test	365	190	1,213	134	5,317	2,182	5,716	6,121	0	15,012.8	572.87	15,913.6	607.24	6,191.3	224.26	63.7	58.6
		6	10	Herd	365	4	1,146	80	3,580.9	0	2,566.6	10,096.5	89	9,527.9	375.32	9,722.3	383.98				
82	Gr. Hol.	2	11	Test	365	144	986	159	3,463	2,162	4,944	5,706	0	10,534.0	388.45	14,789.7*	545.39*	4,061.1	119.01	32.3	24.1
		4	4	Herd	365	0	1,009	51	4,086	0	2,526	11,636	0	10,718.5	420.67	12,580.4	493.74				
		6	11	Test	365	204	1,226	134	5,788.5	3,277.5	5,064	6,009	0	18,130.7	666.78	18,493.3	680.12				
88	Gr. Hol.	2	1	Herd	290	181	970	93	3,226	0	2,130	5,769	0	6,624.4	293.59	9,916.8	439.51	4,510.5	148.54	44.0	32.7
		3	2	Test	290	0	1,104	108	4,250	1,740	4,701	4,504	0	11,717.2	477.98	14,763.7	602.25				
		4	9	Herd	290	138	1,094	10	3,274	0	2,048	8,056.9	51	9,340.1	412.70	10,589.7	467.91				
91	Gr. Hol.	2	7	Test	365	100	1,172	63	4,857	2,172	5,304	5,576	0	15,565.8	608.66	21,013.8	821.69	11,893.1	459.47	130.4	126.8
		4	1	Herd	365	149	1,247	32	2,333.8	0	2,908	14,475	0	7,606.7	302.09	9,120.7	362.22				
94	Gr. Hol.	2	4	Test	365	140	1,044	304	5,029	2,087	5,506	4,632	0	14,984.7	474.02	20,978.6	663.63	5,462.6	187.88	35.2	39.4
		3	9	Herd	365	174	1,148	166	3,467.8	0	4,145	11,456	0	12,483.9	383.91	15,508.0	476.91				
		5	1	Test	365	215	1,310	139	5,484.5	3,096.5	5,228	5,268	0	19,231.7	610.96	20,962.6	665.95				
229	Hol.	2	7	Test	365	37			5,773	2,251	4,336	8,196	0	20,063.8	631.50	27,086.1	852.53	12,331.3	346.02	83.6	68.3
		6	1	Herd	365	68	1,212	38	4,949	0	3,827	13,771.5	0	14,105.6	484.22	14,754.8	506.51				
254	Hol.	3	7	Test	328	144	1,283	242	4,574	1,821	4,875	6,171	0	13,336.1	436.99	16,136.7	528.76	5,365.4	178.43	49.8	50.9
		5	0	Herd	328	174	1,306	190	3,683.7	294	2,228	8,325	107	9,694.2	315.30	10,771.3	350.33				
256	Hol.	2	6	Test	338	40	1,163	238	4,799.2	2,016.5	4,238	5,272	0	12,914.0	457.79	17,563.0	622.59	3,123.6	92.70	21.6	17.5
		4	1	Herd	338	164	1,255	107	4,125.9	100	2,598	6,116	123	12,042.5	441.93	14,439.4	529.89				
258	Hol.	2	5	Test	365	151	1,161	196	4,629.3	2,114	5,419	5,674	0	14,115.2	449.89	19,479.0	620.85	7,989.8	214.24	69.5	52.7
		3	9	Herd	365	210	1,256	241	3,420.9	0	2,720	6,448	147	9,248.8	327.32	11,489.2	406.61				
402	Jer.	2	3	Herd	365	186			2,581	0	2,068	8,327	69	6,325.6	361.10	7,790.2	444.70	5,297.1	292.25	68.0	65.7
		3	6	Test	365	119	857	213	4,313	2,143	4,398	6,336	0	11,185.7	646.45	13,087.3	736.95				

408	Jer.	6	5	Test	365	0	1,123	13	5,338.5	2,165.5	6,615	5,676	0	14,455.4	816.30	14,455.4	816.30	4,858.4	277.46	50.6	51.5
		8	8	Herd	365	0	1,080	53	4,862.3	0	1,832	7,568	153	9,539.4	535.61	9,597.0	538.84				
409	Jer.	6	1	Test	332	65	990	42	4,620	1,879	5,304	4,970	0	10,587.1	593.30	10,587.1	593.30	2,700.0	170.37	34.2	40.3
		7	7	Herd	332	231	1,033	25	3,396	0	1,464	6,871	165	7,863.4	421.66	7,887.1	422.93				
411	Jer.	2	6	Test	264	73	857	117	3,260	1,539	2,920	4,052	0	6,395.6	363.72	8,250.3	454.65	2,634.8	167.28	39.9	53.0
		3	9	Herd	264	168	843	50	2,992.8	0	1,935	6,718.5	0	6,386.3	313.18	7,127.6	349.53				
		4	10	Herd	264	117	852	20	2,018.5	0	2,567	6,308	0	5,767.5	267.15	6,090.3	282.10				
		6	0	Test	264	100	1,007	5	3,659	2,261.5	3,649	3,346	0	10,237.1	511.53	10,237.1	511.53				
426	Jer.	2	9	Test	334	241	763	142	3,082.5	1,570.5	3,888	5,032	0	7,256.8	472.58	9,071.0	576.55	2,315.9	140.41	32.8	31.4
		3	10	Herd	334	251	800	101	3,648.5	0	1,680.4	7,970	0	6,351.7	402.01	7,057.5	446.68				
		5	11	Test	334	0	915	86	4,269	2,430	4,395	4,262	0	9,486.2	591.71	9,675.9	597.63				
427	Jer.	2	3	Herd	365	126	640	99	2,586.2	0	2,632	9,274	0	5,252.4	265.36	6,468.5	326.80	5,636.9	308.83	87.1	94.5
		3	9	Test	365	154	862	98	4,774.8	1,649.5	3,906	5,545	0	10,618.8	572.64	12,105.4	635.63				
436	Jer.	2	10	Test	365	255	985	199	3,922.4	1,729.5	4,588	5,493	0	8,498.2	461.15	10,537.8	557.99	3,986.0	176.98	51.8	41.4
		3	11	Herd	365	213	982	75	2,751	0	1,775.5	7,978	151	6,962.7	383.80	7,702.1	427.88				
		5	1	Test	365	146	998	136	4,853.5	2,873.5	4,357	5,232	0	12,227.0	632.76	12,838.4	651.74				
438	Jer.	2	8	Test	306	137	999	98	3,514	1,390.5	3,565	3,740	0	7,513.3	426.51	9,466.8	524.61	4,109.6	198.54	76.7	60.9
		3	11	Herd	306	174	1,053	28	2,634.1	0	1,826.5	1,448.5	115	4,842.9	294.77	5,357.2	326.07				
441	Jer.	2	4	Test	365	128	958	278	3,489.5	1,754.5	4,339	5,674	0	6,439.5	397.69	8,500.1	509.04	−72.1	37.77	−0.8	8.0
		3	9	Herd	365	37	1,058	134	4,313.8	0	2,738	9,649	0	7,680.7	422.26	8,572.2	471.27				
467	Jer.	5	7	Test	365	180	1,098	130	4,570.8	1,970	4,326	5,700	0	10,814.5	561.38	11,138.9	572.61	3,065.9	174.07	38.0	43.7
		6	10	Herd	365	103	1,004	53	3,773.4	0	2,333	9,388	53	8,000.3	394.95	8,073.0	398.54				
485	Jer.	2	2	Test	365	190	797	174	5,014.2	1,702	3,933	4,752	0	9,917.0	556.64	13,388.0	729.20	3,731.2	213.73	38.6	41.5
		3	4	Herd	365	100	847	64	3,961.6	0	2,186	3,623	173	8,449.7	451.04	9,656.8	515.47				
Average				Herd		134	1,053	83								Total average				51.2	49.5
				Test		109	1,064	141								Total average of all cows except 91 and 441				49.8	47.8

*Eight per cent added on account of being milked one-half the time twice per day.

two records. Of the 52 records, 27 were made under test conditions and 25 under herd conditions. When a cow had more than one record under the same conditions, the records were averaged before a comparison with the record under the other set of conditions was made. The production of milk and butterfat was corrected for age by applying Clark's (1) factors to both the Holsteins and Jerseys under herd conditions, Gowen's (2) factors to Holsteins under test conditions, and Graves and Fohrman's (3) figures to Jerseys under test conditions.

While all the test records were for 365 days some of the herd records, because of approaching parturition, were somewhat less than this. The length of period used in these calculations was the same for the two conditions and was determined by the time the cows continued to give milk under herd conditions. The average length of period, therefore, was 346.5 days instead of 365 days. Although it was realized that making calculations in this way worked to the disadvantage of the test cows, still it was thought that carrying the records for a full year with the herd cows dry part of the time would give undue weight to the influence of pregnancy. The average number of days from conception to the end of the records as shown in this report was 109 days for the test cows and 134 days for the herd cows. Since the difference in the length of time that the calves were carried was only 25 days, it is believed that the matter of pregnancy exerted but little influence on the results as given.

The weights of the cows in the regular herd were taken for three consecutive days on the first, second, and third days of each month; the weights of the test cows were taken on these same days and also on the fifteenth, sixteenth, and seventeenth of each month. The weights as reported are an average of such three days as were believed to represent most accurately the weights at the beginning and end of the test.

The grain mixture for the test cows was for the most part made up as follows: 200 pounds ground oats, 150 pounds linseed meal, 75 pounds cottonseed meal, 100 pounds gluten feed, 100 pounds, hominy feed, 100 pounds wheat bran, and salt at the rate of 1 per cent. The grain mixture for the herd contained less protein

and no gluten feed. It was made up of 100 pounds ground oats, 50 pounds linseed meal, 50 pounds cottonseed meal, 100 pounds hominy feed, 100 pounds wheat bran, and salt at the rate of 1 per cent. The hay was at least average quality for Eastern alfalfa, and any small difference in quality was in favor of the test cows. The silage was made from corn and was uniformly good. The pasture was a mixture of grasses and clovers with orchard grass predominating. It varied in quality, being good early in the summer and fair later in the season.

The following facts are shown in table 1: The cows on test gained more in body weight than those under herd conditions, which was to be expected in view of the more liberal feeding of the test cows. The percentage of butter fat in the milk was unchanged. The average actual production for test cows was 12,446.6 pounds milk and 544.67 pounds butterfat, and for herd cows 8,776.8 pounds milk and 384.74 pounds butterfat. The average increase of test cows over herd cows, as shown by the corrected figures, is 51.2 per cent milk and 49.5 per cent butterfat. By leaving out one abnormally high cow (no. 91) and one abnormally low cow (no. 441) the averages are 49.8 per cent milk and 47.8 per cent butterfat.

As a rule the greater the production the greater the profit, but this applies to animals kept under similar conditions and does not necessarily hold in the present study. It is a matter of prime importance for the dairyman to know the conditions under which his cows yield him the greatest profit. The following discussion has this as its object.

The average prices paid at this stations for feed and bedding for the past five years are as follows:

Wheat bran	$32.79 per ton
Linseed meal	52.49 per ton
Cottonseed meal	51.74 per ton
Hominy feed	36.50 per ton
Ground oats	42.71 per ton
Dried beet pulp	41.43 per ton
Gluten feed	47.04 per ton
Alfalfa hay	29.90 per ton
Wheat straw	14.04 per ton
Corn silage	8.00 per ton
Pasture per cow	0.12 per day

The labor has been estimated at 40 cents a day for the test cows by assuming that a man who is paid $4.00 for a ten-hour day will milk and care for 10 test cows. It has also been estimated from the work at the station and from correspondence with dairymen that the cost of milking and caring for a cow in the regular herd is about one-half that required for a test cow. The bedding required for a cow in a boxstall is about 13 pounds of straw every day; while only 4 pounds is needed for a cow confined in a stanchion, and that amount is needed only during the winter. The value of the milk has been estimated at 30 cents and 40 cents a gallon, and the profits are figured on the basis of both prices.

From tables 1 and 2 it will be noted that under the conditions which prevailed at this station when the value of the milk is

TABLE 2

Comparison of profits from 22 cows kept under test conditions and from the same cows under herd conditions when milk sells at 40 cents and 30 cents a gallon

	COST OF FEED	COST OF LABOR	COST OF BEDDING	TOTAL COST OF PRODUCTION	VALUE OF MILK AT 40 CENTS A GALLON	PROFIT AT 40 CENTS A GALLON	VALUE OF MILK AT 30 CENTS A GALLON	PROFIT AT 30 CENTS A GALLON
Test	$5,108.39	$3,048.80	$695.59	$8,852.78	$12,732.84	$3,880.06	$9,556.47	$703.69
Herd	3,373.10	1,524.40	98.78	4,996.28	8,978.68	3,982.40	6,738.84	1,742.56

figured at 40 cents a gallon it makes little difference in the total profits whether cows are kept under test or herd conditions. However, if the milk is figured at 30 cents a gallon the cows under herd conditions show considerable greater profit. The higher the price of milk and the lower the cost of feed and labor, the more favorable the test conditions appear. At the prices which prevail here for feed and labor, milk selling for more than 40 cents a gallon will show more profit for test conditions, while milk at less than 40 cents will show more profit for herd conditions.

Possibly a better way to estimate the profit from cows kept under test conditions as compared with those under herd con-

TABLE 3

Increase (+) or decrease (−) in feed and labor cost of keeping cows under test conditions, as compared with herd conditions, at each of four price levels

UNIT ON WHICH PRICE IS BASED	QUANTITIES	PRICES PER UNIT AND INCREASE IN COST FOR QUANTITIES USED							
		(1)		(2)		(3)		(4)	
		Price	Increased cost	Price	Increased cost	Price	Increased cost	Price	Increased cost
Ton	Pounds of grain.....64,940	$25	$811.75	$35	$1,136.45	$45	$1,461.15	$55	$1,785.85
Ton	Pounds of hay.....50,419	10	252.09	20	504.19	30	756.28	40	1,008.38
Ton	Pounds of silage....−67,464	4	−134.93	6	−202.39	8	−269.86	10	−337.32
Day	Days on pasture.....−1,404	0.06	−84.24	0.12	−168.48	0.18	−252.72	0.24	−336.96
Ton	Pounds of straw.....76,220	5	190.55	10	381.10	15	571.65	20	762.20
Hour	Hours of labor.....3,811	0.20	762.20	0.30	1,143.30	0.40	1,524.40	0.50	1,905.50
Total.....			$1,797.42		$2,794.17		$3,790.90		$4,787.65
Cost of extra milk per 100 pounds.....			$2.23		$3.46		$4.70		$5.93
Cost of extra milk per gallon.....			0.19		0.30		0.40		0.51
Cost of extra butterfat per pound.....			0.51		0.79		1.08		1.36

ditions is to find the amount of extra feed and labor required, and then from the difference in production find the cost of the extra production per gallon of milk or pound of butterfat. Table 3 shows four sets of costs varying from those which might obtain in some sections where the farmer raises practically all his feed for cows to those where the dairyman buys all his feed except pasture. By using that set of conditions which most nearly applies to his own case, the dairyman can estimate fairly well whether it will pay him to give his animals test-cow care.

DISCUSSION OF RESULTS

This investigation shows that cows kept under the test conditions which prevail at the Beltsville Station yield approximately 50 per cent more milk and butterfat than cows kept under herd conditions. This is an important point to remember in buying stock on the basis of records. A 400-pound record under herd conditions is equal to 600 pounds under test conditions.

The quantity of production, the cost of feeding and caring for the cows, and the value of the product determine whether or not it will pay to give cows the same care as if on test. With cows such as were used in this work it is obvious that test-cow care and feeding will not pay if the product is to be disposed of for butter making even if both feed and labor are cheap. Since the labor cost per unit of product is greater with lower producing cows, it is evident that the poorer the cows the less likely is the test-cow care to be profitable. As the price of the product increases the stronger becomes the likelihood of test conditions being profitable. Doubtless some dairies which receive high prices for milk could increase their profits by giving their herds test-cow care and feed. In general, however, the herd method of caring for cows is the more profitable.

A great deal has been written about the cost of running a cow on yearly test. Under the conditions of this experiment it is shown that if a dairyman receives 40 cents a gallon for 4.4 per cent milk at the barn and the average yield is around 550 pounds of butterfat a year, about the only cost of testing is that of the

supervisor. If a dairyman receives 30 cents a gallon the cost of testing each cow will be about $50 in addition to the cost of the supervisor.

REFERENCES

(1) CLARK: Jour. Dairy Sci., vii, 2, p. 547.
(2) GOWEN: Milk Secretion, Table 17, p. 55.
(3) GRAVES AND FOHRMAN: U. S. Dept. of Agr. Bul. 1352.

A GRAPHICAL METHOD OF PROPORTIONING AND STANDARDIZING ICE CREAM MIXES*

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This graphical method of proportioning an ice cream mix is believed to be simple, rapid, and of special value, because it illustrates the principle underlying all methods of standardizing.

To illustrate the use of the method it will be assumed that a desired mix is to have 10 per cent fat, 11 per cent msnf, 14.5 per cent sugar, and 0.5 per cent gelatine, and that it must weight 3000 pounds.

The available milk products have the following compositions:

MILK PRODUCT	FAT	MSNF
	per cent	*per cent*
Cream	30.0	6.3
Milk	4.0	8.8
Condensed milk	1.0	27.0

The number of pounds of sugar and gelatine are calculated as usual:

3000 pounds of mix × 14.5 per cent sugar = 435.0 pounds of sugar
3000 pounds of mix × 0.5 per cent gelatine = 15.0 pounds of of gelatine
Total = 450 pounds of products not milk

The pounds of fat and milk solids not fat are determined in the same manner as the sugar and gelatine:

3000 pounds of mix × 10.0 per cent fat = 300 pounds of fat
3000 pounds of mix × 11.0 per cent msnf = 330 pounds of milk solids not fat

The pounds of milk products in the mix are determined by deducting the pounds of products not milk from the total amount of mix.

3000 pounds of mix − 450 pounds of sugar and gelatine = 2550 pounds of milk products

* Received for publication August 1, 1926.

In the 2550 pounds of milk products, which will be made up of cream, milk, and condensed milk, there will be 300 pounds of fat or

$$\frac{300}{2550} \times 100 = 11.764 \text{ per cent fat}$$

and 330 pounds of msnf or

$$\frac{300}{2550} \times 100 = 12.941 \text{ per cent milk solids not fat}$$

The graph used with this method of proportioning the mix is illustrated in figure 1. The per cent of fat is plotted on the vertical axis and milk solids not fat on the horizontal axis. The composition of the cream is shown on the graph by the point *A*. The compositions of the milk and condensed milk are represented by the points *B* and *C* respectively. The per cent of fat and milk solids not fat desired in the 2550 pounds of milk products is indicated by the point *D*. Points *A* and *B*, when connected with a straight line, form the line *AB*, which represents the compositions of all the possible mixtures which can be made by combining cream and milk of the compositions *A* and *B*. A straight line drawn through the points *C* and *D* and extended intersects the line *AB* at *E*. The point *E*, according to the estimate made from its location on the graph, indicates the composition of a mixture of milk and cream with 15.82 per cent fat and 7.66 per cent msnf. The line *CE* represents the compositions of every possible combination of the 15.82 per cent milk and cream mixture and the 1.0 per cent condensed milk. Since the point *D* is obviously the composition of one of these possible mixtures, and since *D* also represents the composition desired in the 2550 pounds of milk products, it follows that the mix can be made by combining the 15.82 per cent mixture of the milk and cream with the 1.0 per cent condensed milk.

The next step in the procedure is to determine the pounds of the milk and cream mixture and condensed milk which combined will make 2550 pounds of mix containing 11.764 per cent fat. The pounds of milk and cream necessary to make the amount of 15.82 per cent mixture required for combination with the condensed milk can then be calculated.

No attention to the milk solids not fat content of the milk products is necessary in the calculations *after* the compositions

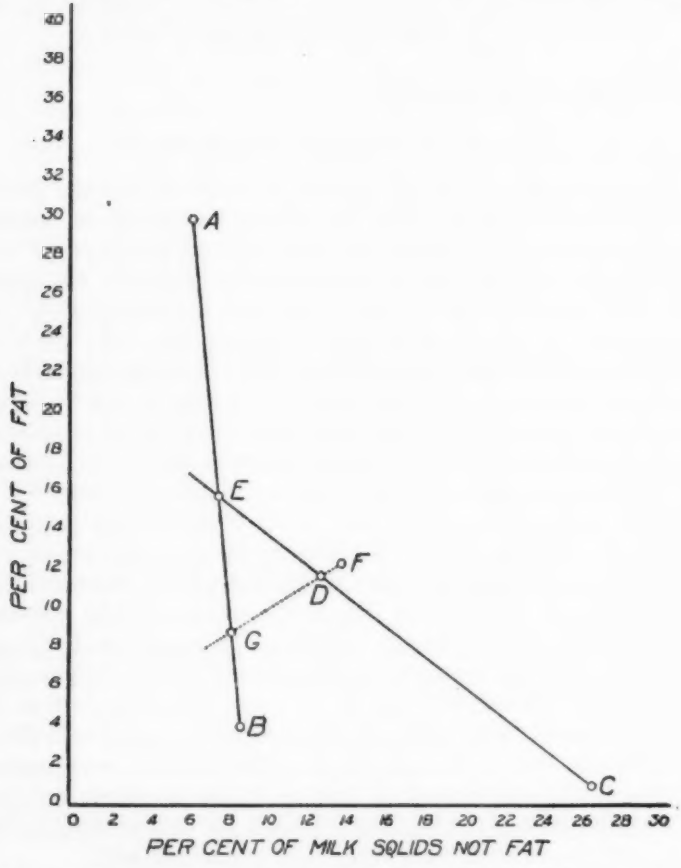


FIG. 1. GRAPH FOR PROPORTIONING AND STANDARDIZING ICE CREAM MIX

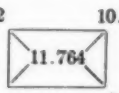
This graph was drawn on Keuffel and Esser standard cross section millimeter paper using the scale: 10 millimeters = 1.0 per cent.

of the milk products have been correctly plotted on the graph. This simplifies the problem to a great extent because any method

for standardizing for fat alone can be used to proportion the ingredients of the mix.

The steps in the calculations by the Pearson Square Method are as follows:

1. Calculate the pounds of 15.82 per cent milk and cream mixture and 1.0 per cent condensed milk necessary to make 2550 pounds of 11.764 per cent mix.



10.764 unit parts of 15.82 per cent milk-cream mixture

4.056 unit parts of 1.0 per cent condensed milk

14.820 unit parts of 11.764 per cent mix

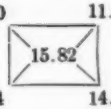
$$\frac{\text{Pounds of condensed milk}}{2550} = \frac{4.056}{14.820}$$

$$\text{Pounds of condensed milk} = \frac{4.056}{14.820} \times 2550 = 697.89 \text{ pounds}$$

The pounds of condensed milk deducted from the total number of pounds of milk products leaves the pounds of milk and cream necessary in the mix.

2550 pounds of milk products − 697.89 pounds condensed milk = 1852.11 pounds of milk and cream testing 15.82 per cent fat

2. Calculate the pounds of 30 per cent cream and 4 per cent milk necessary to make 1852.11 pounds of milk-cream mixture testing 15.82 per cent fat.



11.82 unit parts of 30 per cent cream

14.18 unit parts of 4 per cent milk

26.00 unit parts of 15.82 per cent milk-cream mixture

$$\frac{\text{Pounds of cream}}{1852.11} = \frac{11.82}{26.00}$$

$$\text{Pounds of cream} = \frac{11.82 \times 1852.11}{26.00} = 842.01 \text{ pounds}$$

The pounds of cream deducted from the pounds of milk-cream mixture required in the mix leaves the pounds of milk necessary.

1852.11 pounds of milk and cream−842.01 pounds of cream=1010.10 pounds of 4 per cent milk

Proof of calculations in pounds

	MATERIALS	FAT	MSNF	SUGAR	GELATINE
Condensed	697.89	6.979	188.433		
Milk	1010.10	40.404	53.046		
Cream	842.01	252.600	88.889		
Sugar	435.00			435	
Gelatine	15.00				15
Total	3000.00	299.983	330.368	435	15
Per cent	100.00	9.999	11.012	14.5	0.5

It may happen that a mix which contains wrong amounts of fat and milk solids not fat must be corrected by proper combination with other milk products.

Assume that the 3000 pounds of mix whose formula has already been proportioned contains 10.54 per cent fat and 11.90 per cent msnf, 14.5 per cent sugar, and 0.5 per cent gelatine, and that the milk products available for adjusting the mix to the desired composition of 10.0 per cent fat, 11.0 per cent msnf, 14.5 per cent sugar, and 0.5 per cent gelatine are the same as those used to make the original mix.

It is necessary to know first the per cent of fat and milk solids not fat in the milk products portion of the 3000 pounds of incorrect mix.

3000 pounds mix × 10.54 per cent fat = 316.2 pounds of fat
3000 pounds mix × 11.90 per cent msnf = 357.0 pounds of milk solids not fat

It has been shown that this 3000 pounds of mix contains 14.5 per cent sugar and 0.5 per cent gelatine as the only ingredients not milk products and that there are, therefore, 2550 pounds of milk products in the mix. Since the milk products portion of the mix is the only source of milk fat and milk solids not fat, then in this 2550 pounds portion of the theoretically sugar and gelatine free mix the per cent of fat will be:

$$\frac{316.2}{2550} \times 100 = 12.4 \text{ per cent fat}$$

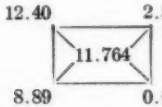
and the per cent of milk solids not fat will equal:

$$\frac{357.0}{2550} \times 100 = 14.0 \text{ per cent msnf}$$

The calculations for the original correct mix show that the 2550 pounds of milk products should contain 11.764 per cent fat and 12.941 per cent msnf. It is necessary, therefore, to add cream and milk to the incorrect mix. The reason for this particular selection of materials will be mentioned later. If the composition of the milk products portion of the incorrect mix is plotted on the graph, it will fall at point *F*. If the line determined by the points *F* and *D* is drawn *from F through D*, it will intersect the line *AB* at *G*. The point *G* represents on the graph the composition of a mixture of 30 per cent cream and 4 per cent milk containing 8.89 per cent fat and 8.30 per cent msnf.

The procedure explained in connection with the proportioning of the first mix is followed again in this standardization.

1. Calculate the pounds of 8.89 per cent milk-cream mixture necessary to add to 2550 pounds of 12.4 per cent mix to give a mixture testing 11.764 per cent.



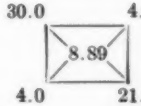
2.874 unit parts of milk-cream mixture

0.636 unit parts of milk products portion of incorrect mix

The total number of pounds of milk-cream mixture necessary to standardize the 2550 pounds of the theoretically sugar and gelatine free mix will be:

$$\frac{2550}{2.874} \times 0.636 = 564.3 \text{ pounds of milk-cream mixture testing 8.89 per cent fat}$$

2. Combine the 30 per cent cream and the 4 per cent milk to make 564.3 pounds of a mixture testing 8.89 per cent fat:



4.89 unit parts of cream

21.11 unit parts of milk

26.00 unit parts of milk-cream mixture

There are 564.3 pounds of milk-cream mixture required, therefore:

$$\frac{564.3}{26.00} \times 4.89 = 106.13 \text{ pounds of cream}$$

and

$$\frac{564.3}{26.00} \times 21.11 = 458.17 \text{ pounds of milk}$$

The summary of the calculations in pounds

	MATERIALS	FAT	MSNF
Incorrect mix	3000.00	316.20	357.00
Cream	106.13	31.83	6.68
Milk	458.17	18.33	40.32
Total	3564.30	366.36	404.00

Only 10 per cent of fat is desired in the corrected mix which, if it contains 366.36 pounds of fat, must weigh:

$$\frac{366.36}{10.0} \times 100 = 3663.6 \text{ pounds of corrected mix}$$

There are 3000 pounds of this mix which contains the desired amount of sugar and gelatine, leaving an excess of 663.6 pounds of the new mix still requiring sugar and gelatine. The amounts of each are calculated, as usual:

663.6 pounds excess mix × 14.5 per cent sugar = 96.22 pounds of sugar
663.6 pounds excess mix × 0.5 per cent gelatine = 3.32 pounds of gelatine

The proof of the calculations in pounds

	MATERIALS	FAT	MSNF	SUGAR	GELATINE
Incorrect mix	3000.00	316.20	357.00	435.00	15.00
Cream	106.13	31.83	6.68		
Milk	458.17	18.33	40.32		
Sugar	96.22			96.22	
Gelatine	3.32				3.32
Total	3663.84	366.36	404.0	531.22	18.32
Per cent	100.00	10.00	11.02	14.50	0.5

The form of graph illustrated in this explanation has one or two interesting characteristics and applications. The line *AE*

and *EB* might be measured in units of length and the amounts of milk and cream calculated by the proportions:

$$\frac{\text{Pounds of milk}}{\text{Pounds of mixture}} = \frac{\text{Length of } AE}{\text{Length of } AB}$$

In the same way the amounts of condensed or milk-cream mixture can be calculated by measuring the proper lines on the graph:

$$\frac{\text{Pounds of condensed milk}}{\text{Pounds of milk products}} = \frac{\text{Length of } ED}{\text{Length of } EC}$$

In selecting the milk products to be used to standardize an off batch of mix, the procedure is not involved. The straight line drawn *from* the point representing the composition of the milk products portion of the incorrect mix *through* the point of composition of the desired mix will intersect the line drawn between the two points representing the compositions of the two milk products which alone can be used to balance the incorrect mix. When the addition of water alone is necessary to adjust the mix, this same straight line, if extended, will pass through the origin of the graph, that is, 0.0 per cent fat and 0.0 per cent milk solids not fat.

In practice, cross section paper mounted on a large drawing board can be used to good advantage; since a large graph is more accurate than a smaller one, when properly ruled. The points representing the compositions of the milk products can be fixed by inserting glass headed pins into the graph at the proper points. The lines can be quickly and accurately shown by stretching fine black thread between the pins. This procedure does not interfere with the accuracy of the method and makes it possible to use the graph for a long time without changing the paper.

ON THE CALCULATION OF THE FREEZING POINT OF ICE-CREAM MIXES AND OF THE QUANTITIES OF ICE SEPARATED DURING THE FREEZING PROCESS*

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In studying the physics of ice-cream freezing and in calculating refrigeration constants for ice-cream work, it is desirable to be able not only to calculate the freezing points of ice-cream mixes but also to determine the quantity of ice that may be separated from the mix at any temperature. Making certain allowable assumptions, it is possible to calculate these values with considerable accuracy.

Van Slyke (1) gives the composition of the average milk as follows:

		per cent
Fat		3.9
Milk solids		8.99
Lactose	4.9	
Protein	3.2	
Salts	0.89	
Water		87.11

Because milk is an animal secretion it is of necessity isotonic with the blood of the animal from which it comes. This means that the freezing point of milk is a fairly constant value, which for cow's milk may be taken as -0.55°C., or in other words, the freezing point of milk is 0.55°C. lower than that of water.

By employing the usual formula for obtaining the molecular weight of an un-ionized substance from the depression of the freezing point of a solvent it can be calculated that the milk sugar accounts for 0.306°C. of the normal freezing-point lowering of milk and that 0.244°C. is caused by the combined action of the milk salts, protein, fat, etc. Not taking into consideration the

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very small effect of the fat and protein upon the freezing point of milk, it is found from these data that the *apparent* molecular weight of the milk salts is 78.6, a figure which will be of considerable value in the calculations given later in this paper.

The molecular weight formula is as follows:

$$\Delta = K\frac{G}{M}$$

In this formula Δ represents the freezing point depression in degrees Centigrade; K the constant, depending on the molecular weight of the solvent (for water 18.6); G the weight of dissolved substance in 100 grams of water; and M its molecular weight.

From the analysis of milk previously given, it is seen that there are 4.9 parts of lactose to 87.11 parts of water, which is equivalent to 5.63 parts of lactose to 100 parts of water. The substitution of the values in the molecular weight formula gives the following:

$$\Delta = 18.6\,\frac{5.63\,*}{342.2}$$

$$\Delta = 0.306$$

* For the purposes of this paper Van Slyke is considered to have expressed the lactose content of milk in terms of anhydrous lactose rather than in those of the monohydrate.

Subtracting 0.306 from 0.55 gives 0.244, the depression of the freezing point of water due to the salts of milk. By again using the molecular weight formula, the apparent molecular weight of the salts can be calculated by substituting 0.244 for Δ and, since there are 0.899 part salts to 87.101 parts water, or 1.032 parts salts to 100 parts water, by substituting 1.032 for G:

$$M = K\frac{G}{\Delta}$$

$$M = 18.6\,\frac{1.032}{0.244}$$

$$M = 78.6$$

From the molecular weight formula and from a knowledge of the composition of an ice-cream mix, the depression of the freezing point of the mix that is caused by the salts can be calculated.

TABLE 1

Freezing point lowering of cane sugar solutions

PARTS CANE SUGAR TO 100 PARTS WATER	PER CENT CANE SUGAR	LOWERING	LOWERING DUE TO 1 PART CANE SUGAR
		°C.	
3.59	3.47	0.21	0.05
6.85	6.41	0.40	0.05
10.84	9.78	0.65	0.06
15 83	13 67	0 95	0.06
19.80	16.53	1.23	0.06
22.58	18.42	1.37	0.06
25.64	20.41	1.58	0.06
28.51	22.19	1.77	0.06
32.22	24.37	1.99	0.06
35.14	26.00	2.15	0.06
37.86	27.46	2.33	0.06
43.72	30.42	2.71	0.06
45.62	31.33	2.82	0.07
50.02	33.35	3.13	0.07
54.74	35.37	3.47	0.07
59.46	37.29	3.81	0.07
64.55	39.23	4.22	0.07
69.74	41.09	4.60	0.07
75.91	43.15	5.07	0.07
82.35	45.16	5.65	0.07
88.67	47.00	6.11	0.07
95.94	48.97	6.76	0.07
102.70	50.65	7.38	0.07
111.30	52.67	8.06	0.07
121.00	54.75	9.02	0.07
131.60	56.82	9.93	0.07
143.10	58.86	10.90	0.07
153.80	60.60	11.69	0.08
165.60	62.35	12.72	0.08
181.70	64.49	13.80	0.08

The other ingredients of the mix that will affect the freezing point are the two sugars, sucrose and lactose. By using the method previously given, it would be possible to calculate the freezing-point depression of an ice-cream mix caused by these

sugars if it had not been shown (2) that sucrose in concentration does not obey the freezing-point law. To find the freezing-point depression then, it is necessary to calculate the *total* sugar concentration of an ice-cream mix, on the water basis, and refer to the actual freezing-point curve for cane-sugar solutions, which has been worked out quite carefully by Pickering (3) and

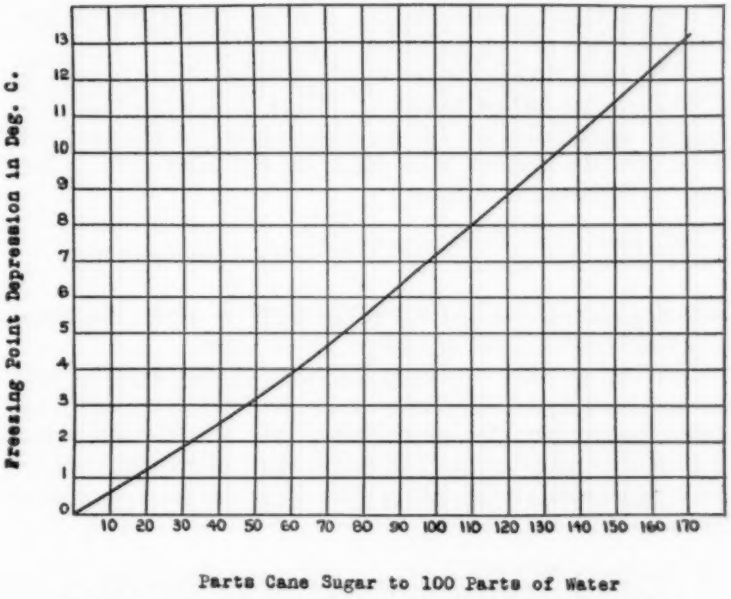

FIG. 1. FREEZING-POINT DEPRESSIONS OF CANE SUGAR SOLUTIONS

checked by P. N. Peter (4) of these laboratories. By adding to this freezing-point depression the depression caused by the salts, a very close approximation of the true freezing point of the mix is obtained.

Two assumptions have been made here which have not yet been proved experimentally: First, that the freezing-point depression caused by the salts obeys the freezing-point law, which is probably true because of the moderately concentrated solutions

encountered; second, that mixtures of lactose and cane sugar, where lactose is present in moderate amounts, will closely follow the freezing-point curve of pure cane sugar in water solution, because the molecular weight of the lactose (anhydrous) is the same as that of cane sugar.

The simplest way of testing the validity of these assumptions is to calculate and determine experimentally the freezing points of some actual ice-cream mixes. For this calculation the preceding method can be simplified somewhat.

Multiplying the number parts milk solids not fat in the mix by 0.545 gives the lactose content. Adding to this the cane-sugar content, multiplying by 100 and dividing by the number parts water give the number parts sugar per 100 parts water. This may be expressed as follows:

$$\frac{(\text{Milk solids not fat} \times 0.545 + \text{Sucrose})\ 100}{\text{Water}} = \text{Parts sugar to 100 of water}$$

Referring then to the freezing-point curve of sugar, the corresponding freezing-point depression (A) is found.

Dividing the number parts milk solids by ten gives the salts content of the mix. Multiplying by 100 and dividing by the water content give the number parts salts to 100 parts water, and this multiplied by 18.6 and divided by 78.6 give the freezing-point depression of the salts. This may also be expressed as follows:

$$\frac{\text{M.S.N.F.} \times 100 \times 18.6}{10 \times \text{Water} \times 78.6} = \text{Freezing point depression due to salts } (B)$$

or

$$\frac{\text{M.S.N.F.} \times 2.37}{\text{Water}} = B$$

$$A + B = \text{Total Lowering}$$

These formulas are now applied to the calculation of the freezing points of several ice-cream mixes made up in such a way that the only difference between them is in the water concentration. This is done in order to calculate and check the

freezing-point curve of a certain basic mix which had the following concentration:

		parts
Total solids		36.03
Fat	12.5	
Sugar (sucrose)	14.0	
Milk solids not fat	9.53	
Water		63.97

By concentration in the vacuum pan, samples of this mix were made which had one-eighth, one-quarter, three-eighths, and one-half of the water removed. The freezing points of these concentrations were determined with the Beckman thermometer in a standard freezing-point apparatus and define the freezing

TABLE 2

Results of calculations and measurements of freezing points of experimental ice-cream mixes

NUMBER	FAT	M.S.N.F.	CANE SUGAR	WATER	TOTAL SUGAR TO 100 H_2O	F.P. DEP. DUE TO SUGAR A	F.P. DEP. DUE TO SALTS B	CAL. F.P. $\left(\frac{A}{+}{B}\right)$	F.P.
	parts	*parts*	*parts*	*parts*	*parts*				
1	12.5	9.53	14.00	63.97	30.00	1.90	0.35	−2.25	−2.29
2	12.5	9.53	14.00	55.98	34.29	2.12	0.40	−2.52	−2.54
3	12.5	9.53	14.00	47.98	40.00	2.47	0.47	−2.94	−3.02
4	12.5	9.53	14.00	40.00	47.86	2.98	0.56	−3.54	−3.62
5	12.5	9.53	14.00	31.99	60.00	3.83	0.71	−4.54	−4.49

point curve of the basic mix. Table 2 gives the results of these measurements as well as of the calculations made by the formulas previously outlined.

It will be seen that there is a very fair agreement between the calculated values and those obtained experimentally.

Experiments appear to justify fully the assumption that the temperature of freezing of an ice-cream mix concentrated in the vacuum pan is the same as the equilibrium temperature that must be attained when the unfrozen portion of the partially frozen unconcentrated mix has the same concentration as the vacuum-prepared sample. These experiments seem to show that ice-cream mixes can be moderately concentrated in the pan

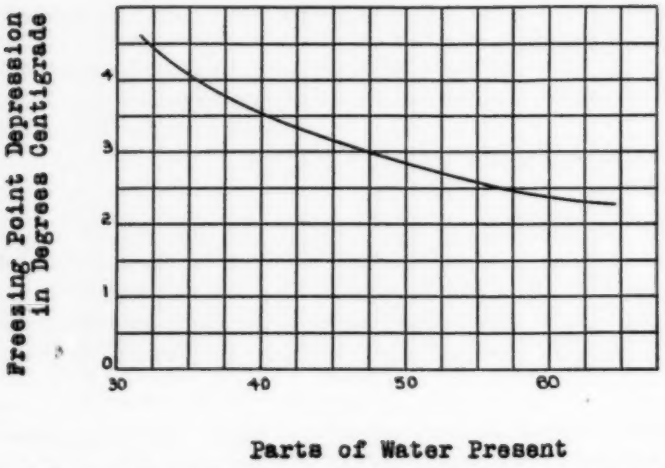

FIG. 2. FREEZING-POINT DEPRESSIONS OF MIXES PLOTTED AGAINST WATER CONCENTRATION

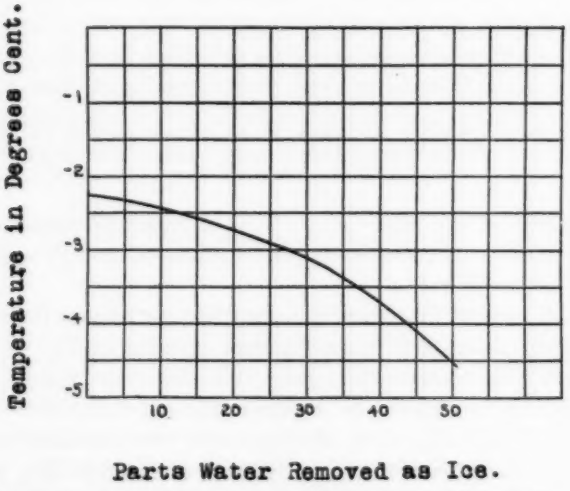

FIG. 3. QUANTITIES OF ICE SEPARATED FROM EXPERIMENTAL MIX AT DIFFERENT TEMPERATURES

and rediluted to normal concentration without any apparent effect upon the physical properties of the mix.

In figure 2 is plotted the freezing point depressions of the experimental mixes against the water concentrations. In figure 3 the freezing points are plotted against the portions of water removed from the basic mix. This latter curve can be used to determine the quantity of ice that may be separated from the ice-cream mix at any freezing temperature. The best way therefore, to determine the quantity of ice that may be separated from any mix at any temperature is to calculate the freezing points of the mix at a number of concentrations, then to plot the freezing-point water-removed curve and from this to estimate the quantity of ice that is frozen out at any one temperature.

Two questions would now naturally arise. First, with the supercooling of the mix in the freezer, how can the equilibrium temperature be determined? Second, may milk sugar crystallizing in the freezer invalidate our calculations, since these calculations are really based upon the assumption that ice is the only material to be thrown out in solid form during the period that the mix is in the freezer?

Unpublished experiments carried out by O. E. Williams and the author show that if a small portion of ice cream is removed from the freezer and its temperature determined, this sample is no longer supercooled and the temperature is very close to the equilibrium temperature. This is true because the quantity of ice separating to attain equilibrium after the portion is removed from the freezer is negligible.

In answer to the second question it can be said that the tendency of lactose to crystallize in the freezer will probably be very slight. This conclusion is reached from the following consideration. Hudson (5) has shown that when lactose is in equilibrium in solution, one part is in the hydrated form and one and one-half parts in the anhydrous form. The anhydrous form is very soluble. When lactose crystallizes, the hydrate deposits, some of the anhydride turns to hydrate and also deposits, the rate of separation then being governed by the rate of transformation, which at low temperatures is shown to be very slow.

The most concentrated mix considered here has about sixteen parts of lactose to 100 parts of water. At −4.5°C. probably about nine parts are soluble. This would mean that our solution is supersaturated to at least seven parts. However, since at least four of these are in the anhydrous form, this solution, while it is potentially supersaturated to at least seven parts, is actually supersaturated to but three. In view of the great tendency (6) of lactose to supersaturate, it seems unlikely that any should crystallize in the freezer. Even if this should happen, calculation shows that the resultant error in determining the quantity of ice that would be frozen at this temperature (−4.5°C.) is about one per cent. At higher temperatures this error would be proportionately less.

In giving the method for calculating the freezing points of ice-cream mixes and in showing how the quantity of ice that may be separated from a mix at any temperature in the freezer can be determined, no reference has been made to the effect of flavoring material on the freezing point of the basic mixes. However, if the water concentration, freezing point, and quantity of flavoring material added to the mix are known, the effect on the freezing points of the basic mixes may be calculated by the principles outlined in this paper. Allowance must be made if any milk product used in making the mix is low in lactose content.

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SOFT CHEESE INVESTIGATIONS*

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INTRODUCTION

The literature contains only few and incomplete references to the manufacture of cream cheese. This is a definite variety of cheese; the process having been evolved from the modification of other soft cheese methods. In consequence, it is possible at present to find this cheese made by different methods; and the result is that our commercial cream cheese varies in quality.

Regardless of the method employed, the cream cheese manufacturers desire a smooth texture and mild flavored cheese. The processes employed at the present time have been perfected with these two objectives in view.

SCOPE OF PRESENT INVESTIGATION

The studies recorded were conducted to observe the methods and result of certain phases of soft cheese making. For these observations it was necessary to prepare curds by numerous methods. The studies relating to soft cheese in general were conducted with curds prepared by a Neufchatel process or this process slightly modified.

The development of a smooth texture and a mild flavor in cream cheese were the objectives of paramount value in this work. It was also essential in the cream cheese studies to develop a cheese which could be sliced. These points were investigated with curds prepared by a cream cheese process or this process slightly modified. Process modifications were employed only in order to obtain added knowledge of methods investigated. For this reason some of the analyses made for comparative purposes do not conform to the normal composition of soft cheese varieties.

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In the recording of data the composition of the milk or cream and the composition of the resulting cheese and whey were recorded for each series under observation. In each series a complete record of the work was recorded.

Milk and cream varying widely in fat content were used during the investigation. Process modification could be observed to better advantage by allowing a wide range of fat content of the milk and cream. For example, setting temperature variation influences could be observed more closely in milk than in cream.

The milk and cream used were analyzed for total solids. Fat determinations were made by the Röse-Gotlieb method. A record was also made of the age, temperature, flavor, and source of the milk. For each lot of cheese 35 or 50 pounds of milk or cream were used.

Curds were analyzed for total solids and fat. Curd yields and quality were recorded. Whey analyses for total solids and fat were made. Due to unavoidable mechanical losses the pounds of whey plus curd did not equal the pounds of milk or cream used. To avoid further mechanical losses the curds were not subjected to pressure.

Homogenization pressures as affecting the resulting curd were studied. The size of fat globules and their influence upon the cheese process were included with the homogenization studies. This also included observations on the clumping properties of the fat globules.

Series of skimmed milk were homogenized in order to determine whether or not homogenization would produce a smooth curd from milk in the absence of fat.

Rennet variations, the use of commercial cutures, and the temperature limits for setting the milk and cream were studied.

Textures, flavors, and keeping quality of the cheese as related to the composition of the milk or cream were investigated.

Pasteurization variations and their influence upon the resulting cheese and whey were investigated. Low and high pasteurization temperatures were employed with low and high fat content milk and cream. The results of the variations upon the cheese texture were very significant.

Several commercial brands of cream cheese were analyzed during the investigation. A report of their composition, texture, flavor and keeping quality is recorded.

A cream cheese process was perfected from the studies conducted at the Station. This method was compared with two methods used by the industry at the present time. An attempt was made to perfect the method commonly employed in draining the curds in cheese-cloth bags.

SOURCES OF MILK AND CREAM

All the milk used in the work was obtained from the Station herd. The cream was also obtained from the Station milk supply. The Station milk used averaged over 5 per cent milk fat, and more than 15 per cent of total solids. This explains the large yields obtained under certain trial conditions as the curds were not subjected to pressure as previously stated.

EQUIPMENT USED

The heat treatment of milk was done in a Creamery Package Horizontal coil pasteurizer. A Burrell surface cooler was also used during the heating and cooling process.

A small Gaulin homogenizer was used for all the homogenization work.

Standard shot gun cans were employed in setting the milk. A simple drain rack was designed to hold the curd from three lots of milk.

The drain sacks were made of cheese-cloth. A close study revealed that this cloth was made of threads 0.28 mm. wide with spaces between them 0.34 mm. square.

The analytical work was performed with standard equipment and according to methods described in Standard Methods of Milk Analysis or in the Official and Tentative Methods of Analysis of the Association of Agricultural Chemists.

EXPERIMENTAL

Effects of homogenization

Five series were prepared for the expressed purpose of studying the homogenization of milk and its effect upon the resulting products. In each series a normal milk was compared with milks homogenized at 2500 and 4500 pounds pressure. For all comparisons reported in this work, unless otherwise stated, the milk was pasteurized at 145°F. (62.8°C.) and held for thirty minutes.

TABLE 1

Showing averages of five series of cheese prepared to compare influences of homogenization

FACTORS STUDIED	HOMOGENIZATION PRESSURE		
	None	2500 pounds	4500 pounds
Per cent milk fat in milk	6.06	6.06	6.06
Per cent solids in milk	15.88	15.88	15.88
Per cent curd yield	26.37	28.25	32.00
Per cent fat in curd	18.24	20.41	18.88
Per cent solids in curd	36.79	41.26	39.19
Per cent whey yield	70.30	69.00	67.82
Per cent fat in whey	0.98	0.11	0.08
Per cent solids in whey	8.34	7.73	7.89
Cheese texture (Av.)	Coarse	Medium smooth	Medium smooth
Cheese flavor (Av.)	Clean	Clean	Clean
Cheese flavor (after 15 days at 40°F.) (Av.)	Clean-acid	Clean	Clean

All milk passed through the homogenizer at 130°F. (54.4°C.) unless otherwise designated.

The major points of interest can be easily followed in the recordings of table 1.

Table 2 has been prepared to show further the variations due to homogenization. In this table the results represent the averages of 18 batches of cream cheese prepared to study homogenization influences.

Of particular interest were the studies conducted at pressures below 2500 pounds. The practical value of establishing a minimum pressure was very important. The point at which drainage was very rapid and fat losses in the whey not excessive was used as a guide in studying minimum homogenization pressures. In this relationship it was established that the beneficial influences of homogenization was completely lost at a pressure below 750

TABLE 2

Showing average of series of cream cheese prepared to study homogenization influences upon low and high fat content cream

FACTORS STUDIED	PER CENT FAT IN CREAM				
	6.06	10.88	14.12	17.47	26.50
Homogenization pressure in pounds	2500	2500	2500	2500	2500
Per cent solids in cream	15.88	19.46	22.98	25.46	No analysis
Per cent curd yield	28.25	31.00	38.00	50.60	58.60
Per cent fat in curd	20.41	37.50	No analysis	No analysis	No analysis
Per cent solids in curd	41.26	47.75	45.50	44.83	No analysis
Per cent whey yield	69.00	68.50	61.50	49.00	41.50
Per cent fat in whey	0.11	0.21	0.22	0.20	1.19
Per cent solids in whey	7.73	7.32	7.67	7.50	8.23
Cheese texture (Av.)	Medium smooth	Medium smooth	Smooth	Very smooth	Very smooth
Cheese flavor (Av.)	Clean	Clean	Clean	Clean	Clean
Cheese flavor (after 15 15 days at 40°F.) Av.	Clean	Clean	Clean	Clean	Clean

pounds. At 1500 pounds pressure the beneficial influences of homogenization were noticeable in part.

Skim-milk was homogenized at low and high pressures. It was not possible through homogenization to improve the texture of a curd prepared from skimmed milk.

The endeavor to associate the variations due to homogenization with the reduced size of fat globules has been summarized in

table 3. The figures show that smooth texture and reduced size of fat globules resulted from homogenization. It could not be concluded, however, that smooth texture and reduced size of fat globules due to homogenization were directly related. This point was investigated further in connection with the composition and additional homogenization trials. An attempt was made to associate smooth texture with size of fat globules, extent and size of fat clumps, and fat content of the cream in these trials which are reported under the composition studies.

The average size of fat globules was reported as 4.82 microns in diameter for the Station Jersey milk during a previous investigation.[1] The average size of fat globules was reported in this

TABLE 3

Showing the relationship of homogenization to fat globule size and cheese texture

FACTORS STUDIED	HOMOGENIZATION PRESSURE		
	None	2500 pounds	4500 pounds
Number of fat globule measurements averaged	500	500	500
Average size of fat globules in microns	3.88	1.56	0.97
Percentage of fat globules larger than average for normal milk used	54.20	3.40	0.00
Cheese texture	Coarse	Smooth	Very smooth

study as 3.88 microns in diameter. Although this could have been explained as a normal variation in size, it was attributed to the fact that fat globules were measured in raw milk for the first investigation. In this work the fat globule measurements were made with pasteurized milk.

From the studies conducted it was possible to determine that a homogenization pressure of 2000 pounds or above produced the desirable smooth texture of the cheese. From a microscopic study it was possible to determine that a homogenization pressure which reduced the diameter of the fat globules 50 per cent or more was sufficient to produce the desirable influence of homogenization

[1] A. C. Dahlberg and J. C. Marquardt. 1924. Filtration and Clarification of Milk. N. Y. Agr. Exp. Sta., Tech. Bul. 104.

in producing a smooth texture in the cheese. It was also discovered to be essential to have a pressure of 2000 pounds or more in order to reduce the losses of fat in the whey.

Effect of rennet variations

Nine comparisons indicated that variations in the amounts of rennet used in milk did not materially affect the initial drainage of whey from the curd. Excessive amounts of rennet, however, had the deterimental effect of giving the drained curd a rather

TABLE 4

Showing the results of varying the amounts of rennet in nine batches of milk

FACTORS STUDIED	RATE OF RENNET PER 1000 POUNDS OF MILK*		
	1.5 cc.	20 cc.	60 cc.
Per cent milk fat in milk	5.46	5.46	5.46
Per cent solids in milk	15.37	15.37	15.37
Per cent curd yield	31.75	32.75	33.40
Per cent fat in curd	18.25	18.20	18.20
Per cent solids in curd	34.08	33.91	32.43
Per cent whey yield	64.50	66.00	66.50
Per cent fat in whey	0.07	0.06	0.12
Per cent solids in whey	7.24	7.33	7.34
Cheese texture (Av.)	Smooth	Smooth	Smooth
Cheese flavor (Av.)	Clean	Clean	Clean
Cheese flavor (after 15 days at 40°F.) (Av.)	Clean	Clean	Clean

* It was noted throughout the work that very small amounts of rennet produced a satisfactory curd when set at 72°F. for twelve to eighteen hours.

dry appearance and in some trials caused a lumpy curd. The tabulated averages of the rennet comparisons are given in table 4. The rennet variations reported in table 4 were held within definite limits required to form a curd from milk held at 72°F. (22.2°C.) for twelve to eighteen hours. The milk for these comparisons was homogenized at 2500 pounds pressure.

It was observed that a more uniform curd was obtained in the homogenized milk than in the milk which was not homogenized.

This was true because the homogenized milk was homogeneous and allowed the culture and rennet to act equally upon all portions of the milk. The upper layer of the unhomogenized milk contained more fat than the lower layer. As a result the culture and rennet acted upon two layers of varying composition. This terminated in difficulties during the drainage process. Excessive fat losses and a cheese of uneven texture resulted. This condition was observed with milk but trials reported towards the close of this project indicated that these conditions do not hold uniformly for cream. Unhomogenized cream heated to 180°F. (82.2°C.) and held for thirty minutes produced a smooth texture cheese. The fat losses in the whey, however, were excessive. Apparently the heavy creams did not divide into distinct upper and lower layers thus causing the unusual rennet and culture action noted with milk. Likewise, the excess fat in the cream was sufficient to produce a cheese of smooth texture, regardless of heavy fat losses in the whey.

Effect of commercial culture variations

The improper use of commercial cultures in the manufacture of soft cheese proved to be the leading factor in producing off-type curds. Texture, flavor, and keeping quality were affected equally by improper use of pure cultures.

In the cream cheese investigations it was deemed desirable to add sufficient culture to the milk or cream to control flavor without the development of a strong acid reaction. Although this was a delicate point in the case of milk or cream set with rennet, it was established by using a culture that titrated 0.6 to 0.8 per cent expressed as lactic acid being titrated with a tenth normal sodium hydroxide solution. Cultures with a reaction above or below these limits were not satisfactory.

A curd with an expressed acid reaction of 0.2 to 0.5 per cent gave the most satisfactory results. Curds below this limit usually developed an off flavor, whereas higher acid curds regularly developed into a slightly sour cheese.

Curds and whey were not changed in composition as a result of culture variations. Some curds prepared without a culture

TABLE 5

Showing results when culture variations were made

(Milk was set with rennet)

FACTORS STUDIED	RATE OF CULTURE PER 1000 POUNDS OF MILK							
	None	10 cc.	20 cc.	25 cc.	50 cc.	100 cc.	200 cc.	400 cc.
Per cent milk fat in milk	5.72	5.51	5.72	5.51	5.62	5.72	5.72	5.72
Per cent solids in milk	15.34	14.15	15.34	14.15	14.79	15.44	15.44	15.34
Per cent curd yield	22.00	21.75	28.00	23.00	25.00	30.00	31.00	30.00
Per cent fat in curd		22.00		21.50	20.75	18.00	18.00	
Per cent solids in curd	43.46	43.94	38.34	42.47	40.30	34.80	35.26	38.57
Per cent whey yield	74.00	78.00	69.00	77.00	73.00	65.00	64.00	68.00
Per cent fat in whey	0.12	0.19	0.11	0.20	0.13	0.08	0.05	0.09
Per cent solids in whey	7.33	7.73	7.46	7.74	7.71			7.30
Cheese texture (Av.)	Coarse	Slightly coarse	Smooth	Slightly coarse	Slightly coarse	Smooth	Smooth	Smooth
Cheese flavor (Av.)	Bitter	Mild	Clean	Clean	Clean	Clean	Clean	Clean
Cheese flavor (after 15 days at 40°F.) (Av.)	Bitter	Mild clean	Mild clean	Mild clean	Slightly sour	Sour clean	Sour	Sour

developed bitter flavors. Flavor control was possible by using 10 to 25 cc. of culture per 1000 pounds of milk. Greater amounts of culture reduced the quality of the cheese due to acid development.

The proper use of cultures improved the flavor of the curds. Cultures, however, did not influence the texture of the curds in a beneficial manner.

The studies of milk and cream of different composition indicated that an increased fat and solid content tended to inhibit the development of acid flavors.

The above comments will probably indicate more regarding the use of cultures than can be obtained from table 5.

Effect of setting temperature changes

These studies showed that a temperature from 68° to 72°F. (20° to 22.2°C.) was most desirable for a proper curd and acid formation. This temperature was selected from the consideration of developing a proper curd in twelve to eighteen hours with rennet.

The results showed that higher temperatures were very detrimental to the quality of the cheese when a proper curd was desired in twelve to eighteen hours. This was not true with cream cheese set without rennet but set with a culture only. Temperatures below 68°F. (20°C.) produced no objectionable condition in the curds. Employing a temperature below 68°F. (20°C.) had no advantage and added materially to the length of time required to form a satisfactory curd. Low temperatures of setting also introduced a factor of slow and irregular drainage of the whey from the curd.

Throughout the work the importance of maintaining definite temperature control was evident. Rising temperature in the curd during setting favored the production of a granular curd, and excess acid development. With rennet curds, the action of the rennet upon the curd was too severe and caused excessive drainage as a direct result of too high a setting temperature.

It was further noted that allowing the temperature to fall below the normal limits caused difficulties in making the cheese. At

sub-normal temperatures the curds appeared to be properly firmed for heating and draining. In such cases, however, upon the application of heat, it was noticed that the curds were slightly too soft. Although this condition could be controlled to produce a favorable cheese in the majority of cases by slowing the heating process, it introduced factors which made the process very burdensome to the maker.

Composition investigations

The composition of the milk or cream constituted the first factor in determining the nature of the resulting product in soft cheese making. In cottage cheese the typical granular texture was due to a low milk fat content in the original milk used. It was recognized that an increase in milk fat or a physical treatment as homogenization tend to destroy this texture in the manufactured cream cheese.

The makers of cream cheese were confronted with the problem of obtaining a smooth texture by the addition of milk fat and the employment of physical means. The problem of determining the limitation of these methods has been considered in this work.

It has been observed that increasing the homogenization pressure decreases the loss of fat in whey. And further, that increasing the homogenization pressure hinders the separation of whey. To overcome the slow drainage the curd was heated. There was, however, a very definite point beyond which the curd could not be heated.

The viscosity of the milk or cream was affected by the temperature of homogenization.

Experimental results favored homogenization of milk at a temperature of 130° to 140°F. (54.4° to 60°C). Homogenization above these limits resulted in a reduced viscosity, and promoted difficulties in drainage. Employing temperatures below 130°F. (54.4°C.) increased the viscosity, and likewise introduced difficult problems in drainage.

Although it was more difficult to drain the whey from cream homogenized below 130°F. (54.4°C.), it was found desirable with cream of low viscosity to homogenize at temperatures as low as

TABLE 6

Showing relationsip of composition of milk and cream to cream cheese quality

FACTORS STUDIED	PER CENT OF MILK FAT IN CREAM							
	6.82	10.01	11.75	13.26	14.12	15.45	17.50	26.50
Per cent solids in cream	20.04	19.46		22.54	22.98	25.46		
Per cent solids in curd	48.37		47.75	44.83				
Per cent fat in whey	0.29	0.29	0.13	0.15	0.22	0.27	0.15	1.19
Per cent solids in whey	7.32	7.70	6.94	7.20	7.67	7.80	7.20	8.23
Cheese texture (Av.)	Granular	Slightly granular	Slightly granular	Smooth and creamy	Smooth and creamy	Very smooth	Very smooth	Very smooth
Cheese flavor (Av.)	Clean	Clean	Clean	Clean	Clean	Clean	Clean	Clean
Cheese flavor (after 15 days at 40°F.) (Av)	Clean	Clean	Clean	Clean	Clean	Clean	Clean	Clean

110°F. (43.3°C.). This introduced the factor of slow drainage, but it insured a smooth textured curd.

The physical nature and treatment of the milk or cream were considered at the same time composition studies were conducted.

The studies with milk and cream of varying percentages of milk fat showed that a cream containing from 15 to 18 per cent milk fat resulted in a smooth pleasant flavored cheese of good keeping quality. Cream containing more than 18 per cent milk fat caused excessive fat losses in the whey, and in some cases it was very difficult to obtain a proper separation of whey.

TABLE 7

Showing relationship of fat content of cream to size of fat globules and size and number of fat clumps as related to cheese texture

FACTORS STUDIED	PERCENTAGE OF FAT IN CREAM		
	8.43	13.69	17.72
Homogenization pressure in pounds	2500	2500	2500
Number of fat globule measurements averaged	200	200	200
Average size of fat globules	1.68	1.87	2.05
Number of fat clumps per 100 single fat globules counted	44	50	63
Average size of fat clumps in microns	(3.4 × 4.9)	(5 × 6.7)	(7.6 × 8.9)
Cheese texture	Coarse	Smooth	Very smooth

In table 6 are recorded the findings of varying the composition of the milk or cream. Twenty batches of cheese were studied for these comparisons.

The size of fat globules and the size of fat clumps and their number were recorded in connection with the composition studies. The data summarized in table 7 indicated that the size of fat globules and the percentage of fat present control the smooth texture of the cream cheese. The summary of table 3 shows that for milk and cream of like fat content there was an apparent direct relationship between the small fat globules due to homogenization and smooth texture of the cheese. It was not possible

to associate the size of fat clumps and their number with the smooth texture of the cheese. From table 7 it was possible to deduct that the size and number of fat clumps were related in a direct proportion to the amount of fat in the cream. The factors responsible for increased clumping were not investigated as the results did not associate smooth texture with size and number of fat clumps.

Heat treatment and its relationship to the cheese

In order to aid further in the production of a smooth texture in cream cheese and to facilitate the drainage of whey with minimum fat losses, heat treatment studies were conducted. The first point studied related to the temperature of heating the cream. The second study concerned itself with the heating of the curd.

The procedure of heating the milk or cream to 145°F. (62.8°C.) and holding for thirty minutes had a marked influence upon the flavor and keeping quality of the cream cheese. It did not, however, affect the texture of the cheese. It was necessary to heat the milk or cream to 180°F. (82.2°C.) and hold for ten minutes before a noticeable change in texture occurred. It was further noted that heating cream as high as 180°F. (82.2°C.) and holding for twenty to thirty minutes improved further the texture of the cheese. Although a temperature of 180°F. (82.2°C.) held for ten minutes or less fulfilled the requirements for pasteurization regulations, it was deemed advisable to increase the holding time twenty to thirty minutes. By this practice the additional small but positive improvement in texture was obtained. These results were observed with curds that formed at 72°F. (22.2°C.) in twelve to eighteen hours.

An attempt was made to produce a cheese of smooth texture without homogenization by heating cream containing 18 per cent fat to 180°F. (82.2°C.) and holding for thirty minutes. It was possible to produce the desired smooth texture in cheese made from unhomogenized cream by pasteurizing at 180°F. (82.2°C.) and holding for thirty minutes. But the fat losses in the whey from unhomogenized cream were excessive as previously noted in table 1 relating to the observation of milk. Increasing the

pasteurization temperature did not reduce the fat losses in whey drained from curds of unhomogenized cream.

High temperature pasteurization produced a soft curd and required special treatment to facilitate drainage. This in turn resulted in a cream cheese with a very plastic smooth texture. Curds that appeared very soft and mushy required heat treatment for drainage. No definite procedure or temperature could be set for this purpose. Gentle agitation and the gradual application of heat were essential for producing desirable drainage.

It was found necessary to cool the milk or cream to 130° to 140°F. (54.4° to 60°C.) before homogenization in order to control the viscosity. Cream homogenized at a low temperature was very viscous and drained slowly, as previously noted. High viscosity cream always produces a smooth curd.

The experimental results indicated that a curd heating as high as 96°F. (35.6°C.) was necessary to facilitate whey drainage. It was also determined that the time of cooking varied widely under different conditions. As a rule it required from two to four hours of cooking in order to drain the curds with a high milk fat content.

In special cases where the cream cheese was set with a culture and no rennet, it was required to increase the cooking temperature from 96°F. (35.6°C.) to as high as 110°F. (43.3°C.) before proper drainage was possible.

Cream set at 86°F. (30°C.) with normal amounts of culture and rennet required heat treatment to facilitate drainage. These curds formed in four to six hours and never required a temperature above 96°F. (35.6°C.) to facilitate drainage.

Analyses of commercial cream cheese

In an endeavor to establish the composition of commercial cream cheese several samples were purchased and analyzed. These analyses are reported in table 8. The figures in this table indicated that the desirable texture and flavor were obtained in cheese made from high fat content cream. In two cases, however, this was not true. Although samples 5 and 6 in table 8 had the proper texture, they were off-flavor and yeasty. This condition was due either to the use of low grade raw materials, storing the

TABLE 8

Showing composition of commercial cream cheese

CHEESE NUMBER	1*	2*	3	4	5	6	7	8
Fat percentage...	4.50	4.78	41.00	41.00	36.00	37.35	44.82	36.91
Moisture percentage.....	75.92	76.07	48.06	47.00	47.76	47.52	No analysis	No analysis
Flavor.....	Lacking in flavor	Lacking in flavor	Sweet	Sweet	Yeasty and off flavor	Yeasty and off flavor	Sweet	Sweet
Texture.....	Coarse and grainy	Coarse and grainy	Smooth	Smooth	Smooth	Smooth	Very smooth	Very smooth

* Samples 1 and 2 were purchased in bulk. This cheese although sold as cream cheese resembled a very high grade cottage cheese due to its low fat content and granular texture.

cheese at a high temperature, or keeping the cheese over too long a period. The importance of using excellent raw material and not subjecting the cheese to improper temperature or holding it too long were factors essential in the production of an excellent quality cheese.

These cheese varied widely in composition, texture, and flavor. In consequence, their price also covered a wide range. Needless to say, the cheese with a very smooth slightly sticky texture demanded the highest price.

The author has also analyzed samples of cream cheese containing fats other than milk fat. Although these foreign fats produced a very smooth texture, their effect upon the flavor of the cheese was detrimental. The presence of foreign fats in cream cheese can be detected by observing the size and appearance of fat globules. This is not a perfect method of detection and cannot be relied upon in cases when the foreign fat has been homogenized. It can be employed to advantage, however, in a general study of the product with reference to the addition of foreign fats to the finished cheese and the efficiency of homogenization. After the microscopic examination chemical means were used to establish the presence of foreign fats. The addition of foreign fats to cheese is adulteration and should not be practiced.

Cream cheese methods compared

Two methods commonly employed in the manufacture of cream cheese were compared with the method developed at the Station. The first method required 180°F. (82.2°C.) for thirty minutes for pasteurization. The cream was homogenized at 140°F. (60°C.) and 1800 pounds pressure. The cream was set at 75°F. (23.9°C.) with 1 cc. of rennet per 600 pounds of cream. The following day, when the soft jelly-like curd was formed, the curd was gently stirred and heated from 94° to 96.°F. (35° to 35.6°C.). Rivulets of whey on the stirring rod dipped into the curd indicated that the cooking was sufficient. At this point the curd was cooled to 50°F. (10°C.) and after an addition of 1 per cent salt, the curd was drained in bags.

The second method varied from the above method in that the

cream was set at 90°F. (32.2°C.) with 0.25 per cent of culture without the addition of rennet. This method required cooking at 110°F. (43.3°C.) in order to facilitate proper drainage.

The method developed at the Station required a cream containing 15 to 18 per cent and pasteurization at 180°F. (82.2°C.) for thirty minutes. The cream was homogenized at 110°F. (43.3°C.) and 2500 pounds pressure. The cream was set at 72°F. (22.2°C.) with 10 to 25 cc. of culture and 1.5 to 20 cc. of rennet per 1000 pounds of cream. The condition of the milk determined the amount of culture and rennet used. After twelve to eighteen hours, according to the appearance of the curd, the curd was heated until ready for drainage. This heating required two to four hours, and a temperature varying from 94° to 110°F. (34.4° to 43.3°C.), depending upon the nature of the curd. Fine salt was incorporated in the drained curd at the rate of $1\frac{1}{4}$ pounds per 100 pounds of curd.

The cream cheese made by the three methods was smooth in texture. It was necessary to control carefully the acid development in the cheese set with a culture at a high temperature. Failure to do so resulted in a high acid curd of granular texture.

The cheese set with rennet only developed a mild sweet flavor. The cheese made by the other methods developed a mild flavor that was distinctly different from the cheese made from cream set with rennet only.

The practice in the first method described of cooling the cream to 50°F. (10°C.) before drainage was an added precaution to prevent fat losses in the whey. It was also an added precaution to prevent further acid and off-flavor development. The desirability of following this procedure was governed largely by the condition of the raw material and the facilities of cooling rapidly and conveniently.

According to Fisk,[2] the practice in the first method described of

[2] The information regarding the addition of salt before drainage and cold drainage was obtained through the courtesy of Prof. Walter W. Fisk, Cornell University, Ithaca, N. Y. It was also through the courtesy of Professor Fisk that the information regarding the two commonly used methods for making cream cheese was obtained.

adding 1 per cent of salt before draining was a precaution to prevent further acid development in the curd.

Experiments conducted at the Station established this point by showing that the addition of salt hindered the development of lactic acid in milk. Only 2 per cent of salt was necessary to check the acid development in milk to which a culture had been added. The milk treated with salt and incubated at 72°F. (22.2°C.) for eighteen hours titrated less than 0.25 per cent expressed as lactic acid and titrated with a tenth normal sodium hydroxide solution. The control titrated over 0.8 per cent with the same method of titration. Salt added to the control after the acid development had taken place did not alter the titration. The action of salt in checking acid development was further established by titrating the whey draining from salted and unsalted curds.

It was necessary to use a fine salt when salting the drained curd according to the method developed at the Station. Both methods were satisfactory for incorporating salt in the curd. Excellent results were obtained by salting the drained curds when high grade raw materials were used. Salting before draining was found desirable when curds from inferior raw material were prepared.

DISCUSSION

The quality of soft cheese varieties can be improved by homogenization and high pasteurization temperatures of the milk or cream.

The texture of soft cheese can be improved by homogenization. Homogenization also reduces the fat losses in the whey. To improve the texture of the soft cheese and minimize the fat losses in the whey an homogenization pressure of 2000 pounds or more is required. Or, conversely, a pressure sufficient to reduce the diameter of the fat globules 50 per cent or more will aid in the production of the desired texture and minimize fat losses in the whey.

Homogenization at a pressure of 4000 pounds or above further improves the texture of the cheese. It does not reduce the fat losses in whey more than a pressure of 2000 pounds. Difficulties

are encountered in attempting to drain curds produced from milk or cream homogenized above 4000 pounds pressure.

Homogenization of milk at a temperature of 130° to 140°F. (54.4 to 60°C.) is essential to eliminate viscosity variations produced at higher or lower temperatures which interfere with the proper drainage of the curd. Homogenization of cream at 110°F. (43.3°C.) is desirable to insure a smooth textured cheese. By increasing the viscosity of the cream, this homogenization temperature introduces the factor of slow drainage which is compensated by the assurance of a smooth curd.

It is not possible to conclude that the smooth texture of soft cheese is directly related to the small sized fat globules resulting from homogenization. Nor is it possible to associate the size and number of fat clumps resulting from homogenization directly with the smooth texture of the resulting cheese. Cream cheese made from cream containing high percentages of fat is smoother in texture than a cheese made from a thinner cream, due to the additional fat. This is true regardless of the size of fat globule clumps and their number.

Rennet variations influence the quality of soft cheese. Excessive amounts of rennet result in a dry-appearing cheese. Rennet action is more uniform on homogenized than on unhomogenized milk. This is not uniformly true with cream. Cream cheese set with rennet requires sufficient rennet to form a soft jelly-like curd at 72°F. (22.2°C.) in twelve to eighteen hours. One and five-tenths to 20 cc. of rennet per 1000 pounds of milk to which a culture is added is sufficient to produce the desired curd. This curd is formed in four to six hours when the setting temperature is raised to 86°F. (30°C.) and the maximum amount of rennet used.

Neufchatel and cream cheese flavors are improved by the proper use of a commercial culture. Small quantities of culture are used to control off-flavor developments. Ten to 25 cc. of culture per 1000 pounds of milk are required to control flavors in soft cheese. The use of excessive amounts of culture is deterimental, resulting in the development of sour curd, and also a granular condition of the curd. Cultures properly used have no effect upon the curd

texture. It was observed, however, that certain proportions of culture and rennet were responsible for a granular condition in the curd.

Neufchatel and cream cheese are set at 68° to 72°F. (20° to 22.2°C.) to produce the desirable curds in 12 to 18 hours. Temperatures below 68°F. (20°C.) introduce subsequent drainage difficulties. Temperatures above 72°F. (22.2°C.) result in granular and sour curds, when set twelve to eighteen hours.

The fat content of milk or cream influences the texture and flavor of soft cheese. Fat content and homogenization are closely associated in controlling soft cheese texture. Cottage cheese is granular in texture, and this texture cannot be made smooth by homogenization, due to the lack of fat in the skimmed milk used.

Neufchatel cheese texture is improved by homogenization of the milk. Homogenization of milk reduced the fat losses in the whey.

A very desirable texture cream cheese results from high temperature pasteurization and homogenization of cream containing 15 to 18 per cent fat.

Pasteurization of milk or cream at 145°F. (62.8°C.) and holding for thirty minutes improves the flavor and keeping quality of soft cheese. Pasteurization of milk or cream at 180°F. (82.2°C.) and holding for ten to thirty minutes improves the flavor and keeping quality of soft cheese. This high temperature also has a beneficial influence of producing a smooth texture in the cheese at 72°F. (22.2°C.) for twelve to eighteen hours. It is possible with cream containing 18 per cent fat by pasteurizing at 180°F. (82.2°C.) and holding for thirty minutes to produce a smooth-textured cheese. This texture is equal in smoothness to a cheese prepared from homogenized cream. The unhomogenized cream subjected to a high pasteurization temperature caused excessive fat losses in the whey.

Cream cheese prepared from cream containing 15 per cent or more fat set with culture and rennet, or with rennet only, requires special curd heating for drainage. It is necessary to heat the curd to 94° to 96°F. (34.4° to 35.6°C.) during a period of two to four hours to facilitate proper drainage. Cream cheese prepared

from cream containing 15 per cent more fat and set with a culture required a curd heating as high as 110°F. (43.3°C.) to facilitate proper drainage.

Commercial brands of cream cheese usually contain 48 per cent moisture and 40 per cent fat. Foreign fats in cream cheese and the efficiency of homogenization are studied by the aid of the microscope. Chemical analyses are required to establish definitely the presence of foreign fat in cream cheese.

Cream cheese was made successfully by three methods. One method required rennet, the second method required a culture, while the third method, developed at the Station, required a culture and rennet for setting the cream.

For comparative purposes it was not found advantageous to drain the curds under pressure. Consequently, the yields and composition were not comparable to commercial cheese.

Setting cream cheese with rennet only required absolute temperature control for the development of a proper curd. Cream cheese set with a culture developed a granular texture only when the acid development was high. The combined use of a culture and rennet gave the most satisfactory results in the formation of uniform curds. Cream cheese set with rennet only developed a mild sweet flavor. Cream cheese set with a culture, or with a culture and rennet, developed a mild flavor. This flavor was distinctly different from the flavor of the cheese set with rennet only.

Cooling the curd to a temperature of 50°F. (10°C.) before draining was an added precaution to prevent fat losses in the whey and the development of sour and off-flavors.

The curd was successfully salted before or after drainage. The object of salting the curd before drainage was to check acid development. It was possible to salt drained curd successfully by using a fine salt according to the findings at the Station.

SOME OBSERVATIONS ON THE FREEZING POINTS OF VARIOUS CHEESES*

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Inquiries have reached this bureau relative to the freezing point of cheese, which, aside from its scientific importance, is of practical interest, particularly with regard to the storage and transportation of cheese in commerce. A search of the literature has revealed no information on this subject; consequently, some measurements have been made in this laboratory, the results of which are given below. Since the time available for this work was limited, only a small number of observations were possible, but it is thought that they are accurate and comprehensive enough to be of practical value. It may be said that the freezing point will vary with different specimens of the same kind of cheese, depending upon the moisture content and degree of ripening.

Stiles (1) and Carrick (2) have discussed the theory of freezing and the potentiometric determination of the freezing point of various foods.

APPARATUS

The temperature was measured electrometrically by the use of standardized thermocouples with the cold or reference junction at 0°C. These thermocouples were made of No. 26, B. & S. gauge, copper-constantan wires. A Leeds and Northrup Type K potentiometer was used in connection with a Type R galvanometer placed in a Julius suspension. A compartment kept at a temperature of approximately −18°C. served as the cold air bath freezing chamber.

EXPERIMENTAL

Small blocks cut from near the center of the cheese were used as samples. The bare metal thermocouples were buried in the

* Received for publication November 11, 1926.

center of each block about an inch from the surface. On account of the eyes in the Swiss cheese a sample was either ground fine and then compressed, or it was cut in halves, which were clamped together after the junction had been carefully placed between them. The samples were electrically insulated from each other and the ground by placing them upon glass plates in the freezing chamber. Readings of the potential were taken every five minutes until freezing began. After that time they were taken at one or two minute intervals. Observations were made upon a number

TABLE 1

Shows freezing point and moisture content of standard varieties of cheese

NAME OF CHEESE*	FREEZING POINT	MOISTURE CONTENT
	°C.	per cent
Cottage	−1.2	78.7
Cheddar (processed)	−6.9	38.8
Limberger	−7.4†	44.4
Picnic Swiss (processed)	−8.1	
Brick (processed)	−8.7	
Swiss (imported)	−9.6†	
Swiss	−10.0‡	34.4
Cheddar	−12.9	33.8
Roquefort	−16.3†	39.2

* The cheeses were all domestic with the exception of the imported Swiss.

† These were checked by thawing curve values which did not differ from them by more that 0.2°C.

‡ This is the average of three freezing and two thawing curve values, which did not vary more than 0.3°C. Only one of these curves is shown in figure 1.

of cheeses during the thawing of the sample. Moisture determinations were also made upon a few of the cheeses.

Data obtained from these observations are given in table 1 and the relation between the cooling curves of a number of standard varieties of cheese is shown in figure 1.

DISCUSSION

It is known that supercooling, or the lowering of the temperature below the freezing point without ice formation, occurs in many substances. A little supercooling is desirable in order to

show the subsequent rise to the equilibrium point and to give positive evidence of the initial ice formation. However, this supercooling effect and the marked lag in the rise in temperature

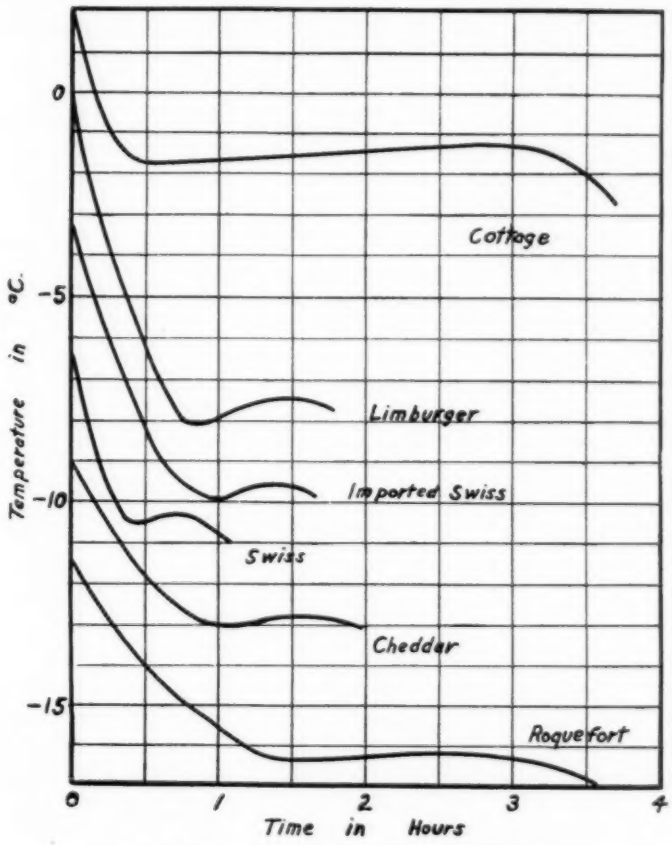

FIG. 1. FREEZING CURVES OF VARIOUS CHEESES

following the initial solidification result in errors, the magnitude of which depends upon several factors, such as the size of the samples and their constitution.

When solutions are supercooled the ice which finally separates

as pure solvent decreases the volume of the remaining solvent, thereby increasing the concentration. In thawing, however, this process is reversed. For this reason freezing points determined by supercooling are likely to be lower than the true values, while those determined from the break in the thawing curves tend to be higher. Therefore, a close agreement between measurements made by both methods serves to confirm their accuracy.

The fact that the supercooling which occurred was not excessive and the values were only about 0.2°C. lower than those from the thawing curves indicated that the errors were negligible. Therefore, no corrections were applied to the freezing points which were taken from the highest point on each curve on the rise after supercooling.

The low freezing point of the Roquefort cheese is probably due to its relatively high salt content.

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THE EFFECT OF HEAT TREATMENT OF SKIM MILK UPON THE BAKING QUALITY OF THE EVAPORATED AND DRIED PRODUCTS*

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It is well known that the heat treatment to which a raw milk is subjected affects the stability of its evaporated product to sterilization temperatures. This fact is made use of in the evaporated milk industry, where maximum stability and good body of the products are desirable qualities. In the case of condensed milks it has been found that "thickening" is favored if temperatures of forewarming near the boiling point are used.[1] The phenomena which are concerned in these cases are probably the result of a change in the degree of hydration and in the degree of dispersion of the proteins in the products.

With these facts in mind, as well as those relating to flour strength, it seems reasonable to suppose that the degrees of hydration and dispersion of the proteins, as indicated by the consistency or body of a product, might affect the property of a bread dough mix in baking.

In addition to the heat treatment in the raw state, milk used in the manufacture of dry milk has the possibility of being further affected by the temperatures to which it is subjected in the manufacturing process.

EXPERIMENTAL

Several preliminary experiments indicated that the water-holding capacity of the constituents of milk, as indicated by the body or viscosity of their solution, was not changed when the product was converted into the dry form.

* Received for publication November 18, 1927. 1926 ?

[1] Leighton, A., and Deysher, E. F. Proc. World's Dairy Congress, ii, p.1276–84, (1923).

Erroneous statement. Probably 1926.

Two commercial samples of dry skim mik were selected which were known to have received different heat treatments before being reduced to a dry state. Samples of these dry milks were incorporated in bread dough mixes. Throughout the work the following formula was used in all baking tests:

	grams
Flour	325
Sugar	10
Salt	5
Fat	7
Yeast	10
Dry skim milk (4 per cent of weight of flour)	13
Water—as per absorption	

Experiments to determine the correct amount of water to be used in each case revealed the fact that dry skim milk made from

TABLE 1

The effect of adding varying amounts of water to dough mixes containing different dry skim milks

SAMPLE NO. 1			SAMPLE NO. 2		
Baking number	Water	Volume of loaf	Baking number	Water	Volume of loaf
	cc.			*cc.*	
1	195	1,885	1	195	1,815
2	200	1,870	2	200	1,925
3	205	1,920	3	205	2,130
	213	Not feasible	4	213	2,085

milk which had received the higher heat treatment (sample no. 2 in table 1) seemed to impart to the dough a greater water-holding capacity than when made from milk which had received the lower heat treatment (sample no. 1). Experiments recorded in table 1 indicate that the dough made from sample no. 2 yielded a loaf of greater volume and of better texture than that made from sample no. 1, when the water content was optimum for baking purposes in each case.

The dough mix containing a dry skim milk of low heat treatment to which had been added 213 cc. of water was not feasible for baking because of its consistency.

After determining the optimum quantity of water to use with each dry milk, five bakings were made to determine the different heat treatments of the milk upon volume and texture of the loaf. Table 2 gives the results of these bakings.

TABLE 2

A comparison of the baking quality of dough mixes in which different dry skim milks were used

CHECK—NO DRY SKIM MILK ADDED				NO. 1—DRY SKIM MILK NO. 1* ADDED			NO. 2—DRY SKIM MILK NO. 2† ADDED		
Baking number	Volume of loaf	Weight	Texture	Volume of loaf	Weight	Texture	Volume of loaf	Weight	Texture
	cc.	*grams*		*cc.*	*grams*		*cc.*	*grams*	
1	2,000	477	Good	1,865	496	Good+	2,085	496	Good+
2	2,050	475	Good+	1,940	494	Good+	2,130	494	Good
3	2,020	479	Good+	1,920	497	Good−	2,085	491	Good+
4	2,010	477	Good+	1,850	491	Good+	2,055	496	Good
5	1,990	473	Good	1,885	496	Good−	2,110	503	Good+

* Received a relatively low heat treatment in the manufacture.

† Received the higher heat treatment in the manufacture.

In this table are given also the results of check bakings wherein no dry skim milks had been incorporated into the dough mixes. Figure 1 shows the increase in loaf volume and in break and shred of the loaf when sample no. 2 is used.

FIG. 1. SHOWING THE BREAK AND SHRED AND RELATIVE VOLUME INCREASE OF LOAF WHEN SAMPLE NO. 2 IS USED

The addition of dry skim milk from sample no. 1 has no material beneficial effect upon the loaf except to increase its weight

over that of the check loaf. On the contrary, there seems to be a slight binding action when sample no. 1 is used. The weights of the loaves containing samples no. 1 and 2 are approximately equal.

The results reported in table 2 are representative of those obtained in a number of bakings in which various dry milks were used. They also show that the conditions to which milk is subjected prior to and in the manufacturing process affects the quality of its powder for baking purposes.

The variation in the water-holding capacities of dough mixes containing different dry milks (table 1) should manifest itself in the viscosity or body of a solution of the dry milk. Forty per cent solutions were therefore prepared and their relative viscosities determined,[2] as shown in table 3.

TABLE 3

Showing the relative viscosities of forty per cent solutions of the samples of dry skim milks used in baking tests (table 2)

SAMPLE NO. 1	SAMPLE NO. 2
2.50–3.00	25.0–33.0

In the same concentration of solids sample no. 2 shows a marked increase in viscosity over that of sample no. 1.

In order to ascertain the relative values of various temperatures of heat treatment and to correlate heat treatment of a milk, viscosity of its concentrated solution and baking quality, fresh skim milk was heated in a water bath for different lengths of time at the chosen temperatures and condensed to approximately 40 per cent solids. Relative viscosities were determined upon each of the samples at 40 per cent, 30 per cent, and 20 per cent concentration of solids. The results are plotted in figure 2.

The results indicate that heating a milk for a short time at

[2] The values given in table 3, and plotted in figures 2 and 3, were obtained with a viscosimeter of the Ostwald type, and hence the term "relative viscosities" is used. The shape of the curves indicate, however, that structural properties are dealt with at the higher concentration and therefore properties of plastic flow are concerned.

85° or 95°C. has a marked effect upon the body of the product when reduced to 40 per cent solids. The effect is not so noticeable at 75°C. To obtain a marked increase in viscosity the time of heating at this temperature seems to be about four hours. A temperature of 65°C. apparently has little effect upon the viscosity even after four hours of heating. The shapes of the curves for the different temperatures readily explain the reason

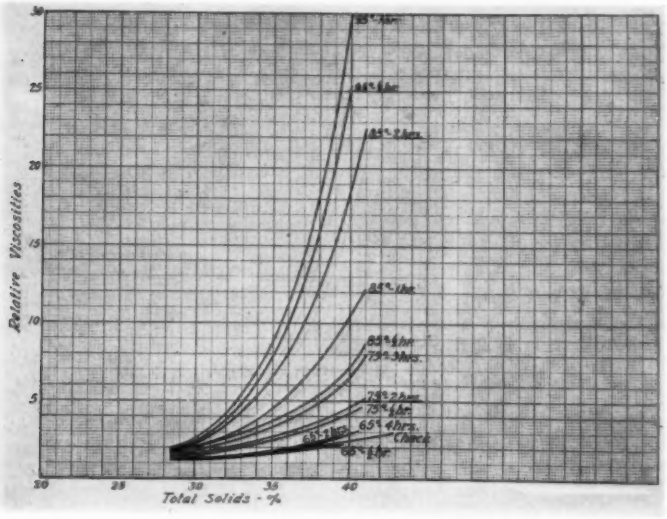

FIG. 2. SHOWING THE RELATIVE VISCOSITIES OF VARIOUS CONCENTRATIONS OF SKIM MILKS WHICH HAD BEEN HEATED AT DIFFERENT TEMPERATURES FOR VARYING PERIODS OF TIME

for wide differences in the bodies of 40 per cent solutions of milk heated at various temperatures. The change in the body of the product with increase in the temperature of heating is abrupt. The relative effects of these temperatures are better shown in figure 3 where the relative viscosities of 40 per cent solutions obtained for each temperature are plotted against the time of heating.

Table 4 gives the results of baking tests upon the various

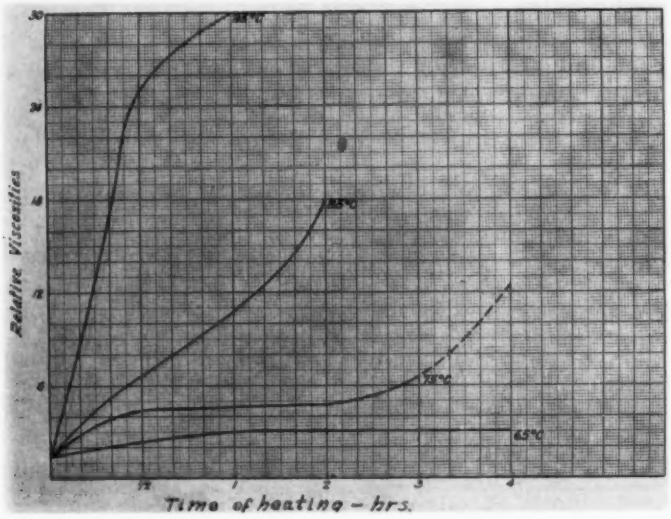

FIG. 3. SHOWING THE RELATIVE EFFECTS OF VARIOUS TEMPERATURES AND TIME OF HEATING UPON THE RELATIVE VISCOSITIES OF CONCENTRATED SKIM MILKS OF 40 PER CENT SOLIDS CONTENT

TABLE 4

Changes in baking quality due to variations in heat treatment of the milk used

TEMPERATURE	VOLUME OF LOAF				
	Time of heating				
	½ hour	1 hour	2 hours	3 hours	4 hours
	cc.	*cc.*	*cc.*	*cc.*	*cc.*
65°C. (149°F.)	1,918		1,853		1,854
75°C. (167°F.)	1,942*	2,020	1,969*		2,091
85°C. (185°F.)	1,973	2,027	2,043	2,030	
95°C. (203°F.)	2,037	2,037	2,023		

* Different flour used.

samples prepared and used in the experiments reported in figures 2 and 3. The product was used in amounts equivalent to 4 per cent, of the weight of the flour, on the dry basis. This table

indicates a definite correlation between the viscosity of a 40 per cent solution of a dry skim milk and its baking quality. Heating at 65°C. for four hours changed the viscosity of a 40 per cent solution only slightly (fig. 2). Very little change was noted in baking quality (table 4). A temperature of 75°C. produced a change in viscosity when continued for four hours. This sample also produced improved baking quality when added to the mix. Temperatures of 85°C. and 95°C. for shorter periods of time produced high viscosities in 40 per cent solution of the samples with corresponding improvement in baking quality.

Though only volume of loaf is recorded here it may be stated that improvement in texture was always noted with increase in volume. The weights of the loaves remained approximately constant.

To test the feasibility of viscosity of a 40 per cent solution of a powder as a criterion of baking quality several commercial samples of spray powders were chosen, the viscosities of 40 per cent solutions (dry basis) were determined, and baking tests were made.

In general it may be stated that a powder producing a 40 per cent solution of high viscosity seems to yield a better loaf than does one producing a low viscosity solution at that concentration.

DISCUSSION

During the progress of the work it was observed that various flours responded differently to the addition of dry skim milk. The increase in volume of loaf over that obtained in bakings where no skim milk was used was not appreciable in some cases, though the texture seemed improved. The problem with which we are concerned, however, was not that of increase of loaf volume and improvement of texture over that obtained in experiments where no skim milk was added, but was rather the variations in properties caused by additions of skim milks receiving different treatments in the manufacturing processes. The flours used, therefore, were those which showed the greatest variations. The problem of increased yield and adaptability of flours is one that is beyond the scope of this work.

Results of experiments indicate that the method of treatment of a skim milk has a marked effect upon the property of its powder to influence the baking quality of a bread dough mix.

The data presented upon the viscosity of milks heated at various temperatures, as well as the facts relating to the "thickening" of condensed milks, show that the changes in the milk caused by heat have an effect similar to that of an increased hydration of the proteins. The correlation between the changes in the body of the solution of the milk used and the results of baking tests seems to show that the magnitude of this physical property, obtained under certain conditions, is a criterion of whether or not a skim milk will have a material beneficial effect upon the baking quality of a dough mix into which it has been incorporated

Results given in table 2 show that the milk which had received a low heat treatment (sample no. 1) seemed to have a slight binding effect upon the dough in baking.

The temperature to which this milk had been subjected in the manufacturing process were not sufficiently great to coagulate the albumin; hence it seems probable that the binding action may be attributed to this constituent. Preliminary experiments seem to verify the correctness of this idea.

ACKNOWLEDGMENT

The baking tests presented in this paper were carried on in the laboratories of the Bureau of Chemistry under the supervision of L. H. Bailey of that bureau. We are indebted to the Bureau of Chemistry and especially to Mr. Bailey for the courtesy and cooperation which made these experiments possible.

THE RATE OF ACID PRODUCTION IN HEATED MILK*

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Extensive data on the effect of heating on acid formation in skim milk have been obtained, and plots of these data at various temperatures have been published.[1] For practical use it has been desirable to combine these curves of acid production against time at a single temperature into a single curve of time rate of acid production against temperature of heating. By interpolation

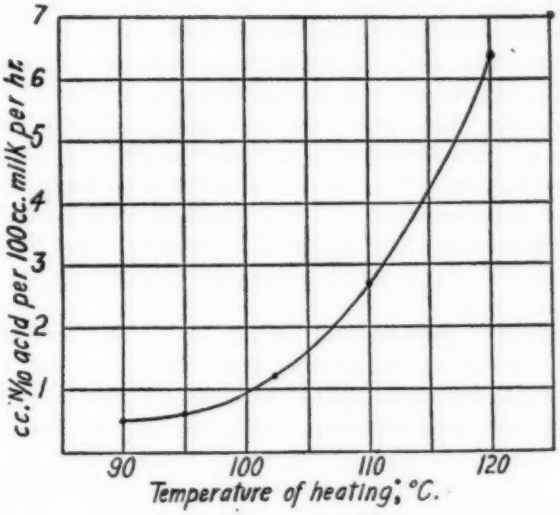

FIG. 1.—RELATIONSHIP BETWEEN RATE OF ACID FORMATION IN MILK AND TEMPERATURE OF HEATING.

from this curve may be determined the rate of acid production at any intermediate temperature and thence may be calculated actual concentrations of acid formed at this temperature over a given time. It is with the hope that other workers may be saved the necessity of accumulating and arranging similar data that this curve is published herewith.

* Received for publication January 5, 1927.

[1] Whittier, E. O., and Benton, A. G., Jour. Dairy. Sci., 1927, x, 126.

INHERITANCE OF BUTTERFAT PERCENTAGE IN JERSEY COWS*

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For many years milk of the different dairy breeds has been advertised as containing a certain definite percentage of butterfat. The American Jersey Cattle Club has proclaimed that the test of Jersey milk averages approximately 5.36 per cent. That this percentage varies only slightly with age, is proved by a study of all the 365-day records completed to January 1, 1926.

The records that have been completed each year since the adoption of the Register of Merit indicate that over a period of over twenty-three years the fat percentage of Jersey milk has remained quite constant. This is shown in table 2 which gives the butterfat percentage and total fat production for the first six years after the adoption of the Register of Merit and for the last four years.

The average percentage of all the yearly tests completed is 5.365 per cent, which means that there were many records averaging lower than this, and of course, many more with higher tests. The increase in total yearly fat production indicates that breeders have constantly striven for increased yields. Their success is evident. It is also shown that the greater fat production has been accomplished only by increasing the milk producing capacity of the Jersey cow. This may be accounted for in two ways; either there is less variability in the percentage of fat than in the milk yield, or it is because dairymen have heretofore paid little attention to the butterfat percentage in their breeding operations. If the percentage of fat in milk is a definite character, inherited separately and independently of other factors, it would appear that breeders were neglecting to use an important tool for the improvement of dairy production.

* Received for publication March 11, 1927.

Roberts, (1) in an investigation conducted in 1918, found a negative correlation between the percentage and milk yield of

TABLE 1

AGE	NUMBER OF 365-DAY RECORDS	AVERAGE FAT PERCENTAGE
		per cent
Yearling	1,365	5.433
Jr. 2	4,091	5.437
Sr. 2	1,901	5.469
Jr. 3	2,010	5.427
Sr. 3	1,550	5.424
Jr. 4	1,537	5.417
Sr. 4	1,291	5.374
5 years	2,256	5.321
6 years	1,653	5.253
7 years	1,226	5.265
8 years	802	5.248
9 years	511	5.215
10 years	296	5.182
11 years	169	5.163
12–23 years	201	5.273
All ages	20,859	5.365

TABLE 2

YEAR	NUMBER OF 365-DAY TESTS	AVERAGE YEARLY BUTTERFAT	AVERAGE YEARLY FAT PERCENTAGE
		pounds	*per cent*
1904	18	348.61	5.402
1905	48	399.02	5.451
1906	78	403.53	5.315
1907	92	433.71	5.482
1908	103	430.83	5.441
1909	173	425.42	5.430
1922	2431	487.34	5.368
1923	1979	512.32	5.392
1924	1498	519.99	5.375
1925	1191	529.94	5.362

Jerseys, Guernseys and Holsteins. For the Jersey breed he reported a correlation of -0.354 ± 0.013. This was a more pronounced negative correlation than for the Guernsey and Holstein

breeds. Wilson (2) however, states that the characters of fat percentage and milk yield are independent and have no effective influence upon each other. Graves (3), from a study of Holstein sires, also concluded that in Holstein cattle the percentage of

TABLE 3

Analysis of records with high fat percentages

Test of 80 cows with high tests who have tested dams	6.958 %
Test of 80 dams of cows who have high tests	5.952 %
Difference	1.006 %
Test of 63 cows with high tests who have tested sisters out of same dams.	6.988 %
Test of 63 maternal half sisters of 63 high testing cows	5.834 %
Difference	1.154 %
Test of 41 high testing cows who have both tested dams and tested maternal half sisters	6.985 %
Test of 41 dams of above high test cows	5.885 %
Difference	1.100 %
Test of 41 maternal half sisters of above high testing cows who also have tested dams	5.844 %
Difference	1.141 %
Test of 59 high testing cows who have tested paternal grandams	6.984 %
Test of 59 paternal grandams of high testing cows	5.626 %
Difference	1.1358%
Test of 141 high testing cows who have tested half sisters by same sire	6.952 %
Average test of half sisters (by same sire) of high testing cows	5.893 %
Difference	1.059 %
Test of 53 high testing cows who have tested daughters	6.965 %
Test of 53 daughters of high testing cows	6.105 %
Difference	0.860 %
Test of 6 high test cows with proven sons	6.90 %
Test of daughters of 6 proven sons of high test cows	5.78 %
Difference	1.12 %
Average fat yield of 160 high testing cows	494.8 pounds

butterfat and milk yield seem to be inherited separately. His data also indicated that both the sire and dam contribute to the inheritance of the fat test of their daughters and that improvement in yield of butterfat can be brought about by selection for both milk yield and percentage of fat.

It was with the object of continuing this work previously begun by others, and possibly throwing more light on the subject of inheritance of butterfat percentage, that the following study was made.

TABLE 4

Analysis of records with low fat percentages

Test of 44 cows with low test who have tested dams	4.133%
Test of 44 dams of cows who have low tests	4.812%
Difference	0.679%
Test of 41 cows with low tests who have tested sisters out of same dams	4.121%
Test of 41 maternal half sisters out of low testing cows	5.035%
Difference	0.914%
Test of 26 low testing cows who have both tested dams and tested maternal half-sisters	4.140%
Test of 26 dams of above low test cows	4.761%
Difference	0.621%
Test of 26 maternal half-sisters of low test cows	4.905%
Difference	0.765%
Test of 42 low testing cows who have tested paternal grandams	4.130%
Test of 42 paternal grandams of low test cows	4.990%
Difference	0.860%
Test of 111 low testing cows who have tested sisters by same sire	4.168%
Average test of half-sisters (by same sire) of low test cows	4.660
Difference	0.492%
Test of 46 low testing cows who have tested daughters	4.167%
Test of 46 tested daughters of low testing cows	4.910%
Difference	0.743%
Test of 5 low test cows with proven sons	4.19 %
Test of daughters of 5 proven sons of low test cows	5.14 %
Difference	0.95 %
Average fat yield of 135 low testing cows	425.1 pounds

DATA PRESENTED

A study of all the records in the Consolidated Register of Merit volume revealed that of the 21,000 cows listed, 160 had completed long time tests averaging above 6.75 per cent in butterfat. Fifty-three of these records averaged higher than 7.00 per cent. The average percentage of the tested dams of these 160 cows was

determined, and also the fat percentage of their tested maternal and paternal half-sisters. Likewise the yearly fat percentage of the tested daughters of these high testing cows was looked up. Proven sons of these high testing cows were included and the tests of their daughters recorded.

A similar study showed that 135 Jersey cows had completed tests with yearly average butterfat percentages lower than 4.25 per cent. Tests of their dams, sisters and daughters were determined exactly as described for the cows testing above 6.75 per cent.

Of course in a considerable number of cases, either the dam, sisters or daughters were not tested. This reduces the number of animals that can be used in the final analysis. The average results of both these tabulations are presented in tables 3 and 4.

In analyzing these studies too much emphasis should not be given to the final average percentages found. The uniformity of the inheritance of high or low butterfat tests and the amount of variation are important items that cannot be seen in the tables. The averages obtained do show that there is a noticeable tendency for the butterfat percentages to approach the average of the breed. Daughters of extremely high or low testing cows rarely tested as high or as low as their dams. Of the high testing cows there were only ten having tested dams with percentages below the breed average. The average tests of the paternal half-sisters of cows out of these ten dams all exceed the breed average by a considerable amount. In fact, the average tests of the daughters of seven of the ten sires are above 6.00 per cent. This would indicate that the cows with high tests out of average testing dams inherited their fat percentage from their sires. Fifteen of the low testing cows are out of dams with percentages above 5.00, yet in each of these cases the sires of these fifteen cows transmitted especially low tests to all their daughters.

It is significant that as far as known, every cow with a high test was either out of a dam with a percentage considerably above the average for the breed, or else was sired by a bull who transmitted high tests to the majority of his daughters. Similarly,

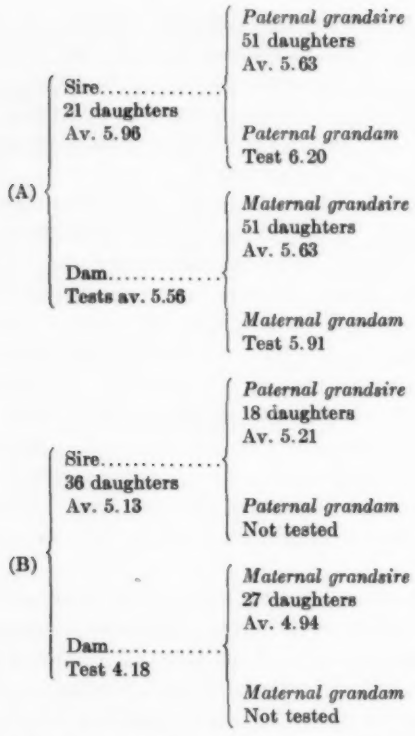
the low testing cows were in every case either out of a low testing dam or by a sire whose daughters were low testers.

There were seven cases of mating a dam testing above 6.00 per cent with a sire all of whose daughters averaged over 6.00 per cent. In each of these cases the daughter averaged above 6.87 and four were above 7.00 per cent.

From the above lists two nationally known sires were chosen for further study. One of these bulls (A) has 20 tested daughters who have an average butterfat percentage on yearly test of 6.57 per cent. Considering the number of daughters, this bull leads the breed in the high tests of his offspring. The other sire (B) equally well known, has 34 Register of Merit daughters with an average butterfat percentage of only 4.71. It happened that the dam of each of the twenty daughters of A was tested. The average test of the dams was 5.72 per cent. As the dams were high testers the bull must have been remarkably prepotent to increase the test an average of 0.85 per cent. This bull has two proven sons whose daughters average 6.63 and 5.54 per cent respectively.

Twenty-five of the Register of Merit daughters of B were out of tested dams. The twenty-five daughters averaged 4.68 while their dams averaged 5.13. This again illustrates a bull especially prepotent except that he transmitted low tests to all of his daughters. Only one daughter did he sire that tested above the average for the breed. B has eight proven sons and each inherited the factor for low tests from their sire. Daughters of these proven sons averaged but 4.98 per cent of fat.

As these two sires were so remarkably prepotent, a study was made of their pedigrees. These are given in skeleton form and explain in a large degree the transmitting ability of both sires. The pedigree of A is a good illustration of the continuous mating of high testing animals with the result that a bull was obtained remarkably prepotent in transmitting high tests to his offspring. In total fat production, the daughters of A averaged 829.6 pounds of fat when calculated to a mature 365 day equivalent, while their dams averaged 752.4 pounds.



To study further the relation between butterfat percentages and total fat and milk production, all of the 365-day records in the Consolidated Volume made by mature cows from five to eight years of age, were arranged in columns according to the test percentages. There were fourteen groups ranging from the lowest tests to the highest. The average fat and milk production of each group is shown in table 5.

All records exceeding 700 pounds of fat were arranged in groups and the average fat percentage of each group determined. These are listed in table 6.

There were 393 yearly records completed during 1926 by cows over five years of age. Table 7 shows the degree of correlation

TABLE 5

Classification of all 365-day records in Consolidated R. of M. Volume made by cows from 5 to 8 years of age

AVERAGE YEARLY FAT PERCENTAGE	NUMBER OF COWS IN EACH GROUP	AVERAGE FAT YIELD	AVERAGE MILK YIELD
per cent		*pounds*	*pounds*
3.50–4.20	22	492.1	12,079
4.21–4.40	80	487.0	11,326
4.41–4.60	203	498.9	11,087
4.61–4.80	364	498.1	10,598
4.81–5.00	552	511.3	10,435
5.01–5.20	641	514.0	10,078
5.21–5.40	625	530.6	10,011
5.41–5.60	648	528.9	9.616
5.61–5.80	511	539.1	9.458
5.81–6.00	359	548.1	9,290
6.01–6.20	236	558.9	9.163
6.21–6.40	128	559.5	8,881
6.41–6.60	79	545.6	8,394
6.61–7.50	65	580.3	8,480

TABLE 6

Analysis of R. of M. records above 700 pounds of butter fat

YEARLY PRODUCTION OF FAT	NUMBER OF COWS	AVERAGE BUTTERFAT PERCENTAGE
pounds		*per cent*
950–1141	39	5.835
900–950	47	5.633
850–900	87	5.637
800–850	161	5.632
750–800	280	5.631
700–750	589	5.487
700–1141	1,203	5.562

TABLE 7

NUMBER OF ANIMALS		MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIABILITY	CORRELATION BETWEEN MILK AND FAT PERCENTAGE	CORRELATION BETWEEN TOTAL FAT AND FAT PER CENT
393	Milk	11433±76.8	2255.0±54.2	19.72±0.47	−0.311±0.0310	
	Per cent fat	5.430±0.018	0.552±0.011	10.16±0.24		
	Total fat	618.8±3.46	101.5±2.44	10.45±0.39		+0.233±0.0334

between milk and fat percentage and between total fat production and fat percentage of these tests.

The results shown by tables 5, 6 and 7 indicate that there is a correlation between total fat production and percentage of butterfat and that the fat production increases as the fat percentage increases. The milk yields shown in tables 5 and 7 agree with the findings of Roberts (1) in that they indicate a negative correlation between fat percentage and milk yields. It is very significant, however, that although this negative correlation exists, nevertheless the milk yields do not decrease in the same ratio as the fat percentages increase. In other words the decline in milk flow is not sufficient to prevent the total fat from increasing as the test increases. This is further confirmed in table 5. If the milk flow declined in proportion as the butterfat percentage increases, there would be no justification for the breeding of higher testing cows.

SUMMARY

1. Butterfat is a variable factor although the degree of variability is less than for milk yield.

2. Both the sire and dam contribute to the inheritance of their daughters, governing fat percentage.

3. A parent may be prepotent in increasing the fat percentage of the offspring separately from affecting the milk yield, or may increase or decrease both the percentage of fat and the milk yield.

4. Although there is a negative correlation between milk yield and fat percentage, there is a positive correlation between total fat production and fat percentage.

5. Improvement in total butterfat production can be accomplished by selection for high fat percentage as well as selection for large milk yields.

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SOME OBSERVATIONS ON THE FREEZING POINT OF CREAM AND ITS USE IN DETECTING ADDED WATER*

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The freezing point of milk is a subject that has received a great deal of attention from investigators in widely scattered fields. At present the value is generally accepted as a physiological constant averaging −0.550°C., with a normal variation of from −0.534°C. to −0.562°C. according to Hortvet (1), and from −0.530°C. to −0.566°C. according to Bailey and others (2). The freezing point is now used as a means of detecting added water in milk and a carefully standardized technique has been incorporated, in the methods sponsored by the Association of Official Agricultural Chemists, as an "official method" (3).

The freezing point of cream has not been studied to any great extent. In fact the author has been unable to find any published data dealing with cream as such. However, from cryoscopic data on related substances and a knowledge of the theory of freezing point depression it is not impossible to predict what might be expected.

W. R. G. Atkins (4) found that the addition or removal of fat from milk has no effect on the freezing point.

Parfitt and Taylor (5) show that variations in the fat content of ice cream mixes do not alter the temperature at which they freeze.

Colloidal dispersions, even comparatively concentrated, exhibit very small osmotic pressures and consequently practically negligible depressions of the freezing points of the continuous

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† Published by permission of the Director of the Agricultural Experiment Station. Contribution from the Department of Dairy Husbandry. The Pennsylvania State College, No. 415.

phases, (6) (7). The fat in milk or cream existing as a coarse emulsion, consequently, would not be expected to influence the freezing point of the plasma.

If the fat be removed from milk, skimmilk and cream, either by extraction or centrifugation, the remaining plasmas are identical. Exception to this statement might be taken since Clayton (8) gives data showing that 2 per cent of the casein in ordinary milk is adsorbed or concentrated on the fat globule-plasma interface. Milk in creaming, therefore, might be expected to lose a portion of its colloids to the cream, in which case the respective plasmas might differ. This point, however, would not noticeably affect the freezing point since the colloids, as a class, do not show a noticeable depression phenomenon. The freezing points of milk, skimmilk and cream, then, must be dependent on the concentration of soluble substances in the serum and it can hardly be argued that the serums in question would differ. All of which leads to the conclusion that cream and skimmilk have the same freezing point as the original whole milk from which they are derived.

FREEZING POINTS OF MILK, SKIMMILK AND CREAM

Twelve samples of authentic herd milk were separated and observations made on the resultant skimmilk and cream which were compared with similar observations made on the original whole milk. Cryoscopic readings were obtained following the exact procedure as given in the A.O.A.C. "Official Methods." Fat tests and acidity tests were made in accordance with methods obtained from the same source, with the exception that acidity samples of cream were weighed out instead of measured. The percentages of solids-not-fat represent the difference between the total solids content, obtained by means of the Mojonnier test, and the fat tests.

Elaborate precautions were taken in obtaining the various samples and in holding them prior to analysis and the determination of the freezing points in order that no uncontrolled factors would make a direct comparison impossible. Table 1 gives the

data taken on these samples and is chiefly of interest from the standpoint of the cryoscopic results. Samples No. 11 and No. 12 were diluted before separation with 11.5 per cent and 20 per cent of water respectively. The data seems to confirm the theoretical conclusion made above, namely that the freezing point of skimmilk and cream are identical with that of the original whole milk irrespective of their compositions. An elevation of the freezing point due to added water in milk is equally detectable

TABLE 1

Freezing points of milk, cream and skimmilk

SAMPLE NUMBER	WHOLE MILK				CREAM				SKIMMILK			
	Fat	SNF	Acid	Freezing point	Fat	SNF	Acid	Freezing point	Fat	SNF	Acid	Freezing point
	per cent	*per cent*	*per cent*	*°C.*	*per cent*	*per cent*	*per cent*	*°C.*	*per cent*	*per cent*	*per cent*	*°C.*
1				−0.558				−0.559				−0.558
2				−0.537				−0.540				−0.538
3				−0.546				−0.546				−0.548
4				−0.544				−0.545				−0.545
5				−0.549				−0.550				−0.548
6	4.30	8.47	0.146	−0.545	22.0	6.85	0.121	−0.545	0.03	8.91	0.157	−0.546
7	3.95	8.51	0.162	−0.538	19.5	7.91	0.156	−0.539	0.04	9.05	0.165	−0.536
8	4.05	8.53	0.145	−0.540	27.5	6.32	0.115	−0.538	0.04	9.02	0.154	−0.537
9	4.00	8.53	0.156	−0.543	24.0	7.02	0.121	−0.545	0.03	9.41	0.161	−0.542
10	4.05	8.36	0.141	−0.541	20.0	7.25	0.118	−0.540	0.03	8.80	0.148	−0.540
11	3.80	7.76	0.135	−0.462	25.0	5.97	0.106	−0.461	0.05	8.17	0.138	−0.460
12	3.35	6.89	0.127	−0.429	21.0	5.92	0.085	−0.430	0.02	7.22	0.135	−0.429

in either the skimmilk or the cream after separation. None of the results on a given sample vary to a greater extent than the possible experimental error. It might be mentioned that the freezing points represent the average of three trials all of which checked within 0.003°C. Results varying outside this range were discarded and a new trial made. The cyroscopic method as given seemed to be equally applicable to cream of a richness and viscosity similar to the samples used. The only difference noted in making cream readings was the relative sluggishness of the mercury thread as compared to the movements with milk.

TABLE 2

Watered samples of cream

Freezing points °C.

SAMPLE	UNDILUTED	10 PER CENT ADDED WATER	15 PER CENT ADDED WATER	20 PER CENT ADDED WATER	25 PER CENT ADDED WATER	FAT IN CREAM BEFORE DILUTION
6	−0.545	−0.465	−0.439	−0.386	−0.355	22.0
7	−0.539	−0.464	−0.436	−0.386	−0.357	19.5
8	−0.538			−0.384		27.5
9	−0.545	−0.461	−0.417	−0.386	−0.363	24.0
10	−0.540	−0.465	−0.414	−0.379	−0.353	20.0
Added water calculated from above depressions $W = \frac{100\,(T - T')}{T}$						
6	0	14.7	19.4	29.1	34.8	22.0
7	0	13.9	19.1	28.4	33.8	19.5
8	0			28.6		27.5
9	0	15.4	23.5	29.1	33.4	24.0
10	0	13.8	23.3	29.9	34.6	20.0
Average.....	0	14.4	21.4	29.0	34.1	22.6
Added water calculated from above depressions $W = \frac{A\,(T - T')}{T}$						
6	0	10.8	14.7	22.4	27.3	22.0
7	0	10.4	14.8	22.1	26.8	19.5
8	0			21.4		27.5
9	0	11.0	16.9	21.4	25.0	24.0
10	0	10.4	17.7	23.3	27.4	20.0
Average.....	0	10.6	16.0	22.1	26.6	22.6

DILUTED SAMPLES OF CREAM

Winter's formula given in the "official methods" of the A.O. A. C. for calculating the amount of added water in a sample of milk is as follows:

$$W = \frac{100\,(T - T')}{T}.$$

W, is the percentage of added water; T, the average freezing point depression of normal milk (0.550°C.) or the original freezing point depression, where this is known; and T', the freezing point depression of the sample in question. This formula was used in calculating the added water in a series of cream samples which were diluted at the rate of 10, 15, 20 and 25 per cent respectively. These samples are the same as numbers 6 to 10 in Table 1. The freezing points of these samples are listed in the first portion of Table 2, while results obtained using Winter's formula are given in the second portion of the table. It will be noted that the values obtained here are higher than the actual amount of dilution. This is not surprising when the formula is considered in the light of the theoretical conceptions previously mentioned. Winter's formula is accurate only when the volume occupied by the substances in solution is the same as the total volume of the material under observation. Actually then this formula really gives the percentage of added water based on the serum of the sample. Thus, the greater the difference in volume between the serum and the material as a whole, the more inaccurate will the results be when this forumla is used. In samples of whole milk or skimmilk the discrepancy is not so large that results are very far from accurate, especially where the average normal value 0.055°C. is used for the value of T, but in cream the differences are considerable as indicated in the table. In using Winter's formula for these results T was taken as the freezing point depression of the original undiluted sample.

In the lower portion of the table is shown calculated amounts of water for the samples as in the middle portion, with the exception that a modified formula correcting for the differences in volume between the serum and the cream was used. The formula is as follows:

$$W = \frac{A(T - T')}{T}.^{1}$$

A, is the per cent of serum (by volume) in the sample having a freezing point depression of T'. For all practical purposes

[1] The Cryoscopic method for cream has been accepted tentatively by the A. O. A. C. and this formula is to be used.

the value for A may be taken as the per cent of water in the sample. This is not exactly correct due to a disregarding of specific gravity but is so nearly so that the difference is negligible, especially where the value of T has to be taken as 0.550°C. In this work each diluted sample was not analyzed for water to determine the value of A but the figure was calculated from the analysis of the sample before dilution according to the following formula:

$$A = \frac{b(100 - C)}{100} + C.$$

Here b, represents the per cent of water in the undiluted sample and C, the per cent dilution.

It is noted that the results calculated by the "serum" formula are considerably closer to the actual amounts of water added than the results obtained using Winter's formula. The average algebraic variation in the former is but 1.4 per cent, while in the latter it amounts to 7.3 per cent, roughly five times greater. It is probably unnecessary to state that, when unknown samples of cream are examined, it is necessary to get the value of A by analysis, as it would be rather difficult to calculate it from the percentage of fat when the amount of possible dilution would be unknown.

CREAM SAMPLES FROM DILUTED MILK

Sample No. 11 and No. 12 in table 1 were diluted before separation. Sample No. 11 showed a freezing point depression of 0.536°C., before dilution and sample no. 12 one of 0.558°C. undiluted. Therefore, taking table 1 as evidence the respective cream samples would have had like values in the undiluted state. If the "serum" formula is used and the amount of added water calculated for the cream samples, and in the same way for the skimmilk samples, the results are as follows:

Cream sample no. 11	9.4 per cent added water
Cream sample no. 12	16.8 per cent added water
Skimmilk sample no. 11	13.0 per cent added water
Skimmilk sample no. 12	21.5 per cent added water

Actually there was added to the whole milk samples prior to separation 11.5 per cent and 20 per cent of water respectively. These values are closely approached when calculated from the data by the "serum" formula being 12.2 per cent and 20.7 per cent respectively. It is to be noted, however, that the amounts of added water calculated for the cream and skimmilk portions of these samples do not agree with the amount added to the whole milk, nor do they agree with each other. This of course, is due to the fact that the amounts of serum in the cream and in the skimmilk differ from the amount in the original whole milk and differ more widely as the richness of the cream increases.

In order to determine the amount of water added to a lot of milk prior to separation, from an examination of the cream or the skimmilk, the volumes of each and the amount of added water in each must be known, in which case the following formula may be used.

$$\frac{(C \times W') + (S \times W'')}{C + S} = W.$$

C, is the volume of cream; W' the per cent of added water in the cream; S, the volume of skimmilk; W'', the per cent of added water in the skimmilk and W, the per cent of added water in the original whole milk. This formula naturally would have its limitations when commercial samples are being investigated.

SUMMARY AND CONCLUSIONS

A very brief review of literature, only, is included since no published data was found bearing directly on the subject of this paper.

From data presented it is concluded that cream and skimmilk have the same freezing points as the original sample of milk from which they are separated. If this is so then the normal range must be from -0.530°C. to -0.566°C. as for milk, with an average of -0.550°C.

Winter's formula as given in the "official methods" of the A.O.A.C. is theoretically incorrect and while this fact does not

make it entirely inapplicable for whole milk or skimmilk it shows a great degree of inaccuracy when applied to samples of cream, the degree increasing as the cream samples become richer in fat. Data is given showing the inaccuracies when it is applied to a series of diluted cream samples.

A modified formula is given which is theoretically more accurate and when applied to the same samples of cream mentioned above gives fairly close results as compared with actual amounts of water known to have been added.

The amount of added water found in a cream sample or a skimmilk sample does not correspond with the amount added to the original whole milk, in case such diultion was made before separation; but the latter can be calculated by the formula shown if the weights or volumes of both the cream and skimmilk portions are known together with the respective amounts of water in each, as found by cryoscopic examination and the use of the "serum" formula.

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EFFECT OF TEMPERATURE ON THE VISCOSITY OF SKIMMILK*

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INTRODUCTION

Apparently Soxhlet (1) was the first to study the change in viscosity of milk with temperature. He found that the viscosity of whole milk increased faster than water with lowering temperature. His data are not entirely consistent, but Kobler (2), Taylor (3), and Evenson and Ferris (4) confirmed Soxhlet's finding. Soxhlet attributed this change in relative viscosity of milk with temperature to the casein.

The effect of pasteurization on the viscosity of milk was investigated by Woll (5), using the viscometer designed by Babcock (6). Woll pasteurized his samples by heating for twenty minutes at 67°C., and also by heating in an Arnold steam sterilizer for thirty to thirty-five minutes. The samples were heated in Erlenmeyer flasks closed with cotton plugs. He found that pasteurization under these conditions decreased the viscosity of both milk and cream. The decrease in viscosity of milk was about 4 per cent, while the decrease in the viscosity of cream was about 16 to 17 per cent. Woll found that the viscosity of sweet whey was decidedly increased by pasteurization, the increase being still greater after sterilization. Thus the viscosity of whey was increased by pasteurization, while the viscosity of milk and cream was decreased by it.

Babcock and Russell (7) found that pasteurization, as they carried it out, broke up the clumps or clusters of fat globules which are usually present in raw, normal milk, and they attributed the decrease in viscosity produced by pasteurization to breaking up of these clumps of fat globules. Babcock and Russell (8) (9) found that the addition of calcium sucrate restored the

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viscosity of pasteurized cream and also caused clumping. Babcock and Russell (9) also found that the viscosity of pasteurized cream could be restored by incipient churning, but that in this case the fat globules, instead of being characteristic clusters, were lumps, indicating that the fat globules had coalesced. It was found that this cream would not whip.

The importance of clusters of fat globules as affecting the viscosity of milk has been indicated by Babcock (10) in the following words.

> Although these clumps are not very firmly bound together, they have sufficient stability to remain intact under ordinary conditions, and, on account of the increased resistance which these irregular masses offer to a free movement of the serum, add very considerably to the consistency of milk. This is clearly shown in the comparative thinness of pasteurized product, especially cream, in which the grouping is entirely destroyed, leaving the globules uniformly distributed. Moreover, in such milks, the original consistency is restored to a considerable degree by any process which produces a similar tendency to grouping.

Woll (5) found that the viscosity of the skimmilk also decreased slightly after pasteurization, but he presented rather few data showing this effect.

Sterner (11) concluded that the decrease in viscosity of whole milk by pasteurization was not due to the coagulation of the albumin alone, while Jensen (15) attributes the decrease in viscosity to coagulation of the albumin.

Taylor (3) found that heating milk to the pasteurization temperature of around 65°C., and then cooling the milk to 20°C. and determining the viscosity, decreased the viscosity slightly, while pasteurization at higher temperatures produced a slight increase in viscosity.

Evenson and Ferris (4) heated milk for thirty minutes at various temperatures, and then cooled it to 20°C. and determined the viscosity. They found a decrease in viscosity when the milk was pasteurized at 60° to 65°C. Heating milk to 75° to 80°C. increased the viscosity.

Archard and Stassano (12) found that pasteurization failed to effect the viscosity appreciably.

Since most of this work on the effect of heat on the viscosity has been carried out with whole milk, and as Babcock and Russell indicated that the clumping of the fat globules was an important factor in regulating the viscosity of whole milk and cream, and since clumping is usually more pronounced at lower temperatures, it was thought disirable to make a more careful study of the effect of temperature on the viscosity of skimmilk.

EXPERIMENTAL

The viscosity of skimmilk at various temperatures

All determinations were made with ordinary Ostwald viscometers. The temperature was held constant by immersing the viscometers in a water bath held at the desired temperature. The samples were held in the water bath for fifteen minutes before making the readings. The determinations were made on the same sample of milk beginning at the lowest temperature. A duplicate determination with an aliquot, which had been kept cold during the experiment, was made at the highest temperature and was found to agree in viscosity with the value obtained with the sample used for the entire temperature series. The time of flow of water determined experimentally at the various temperatures was used to calculate the constants of the viscometers. The weight of pycnometers filled with milk and then with water was determined at the various temperatures, and from this data the density of the milk was calculated.

The following equation was used to calculate the viscosity

$$\eta = d\left(At - \frac{B}{t}\right)$$

where η is the viscosity in centipoise, d is the density of the milk, t is the time of flow in seconds, and A and B are constants. The constants A and B were calculated from the time of flow of water at the various temperatures and the viscosity of water as given by Bingham and Jackson (13). This equation repro-

duced the viscosity of water with an average error of less than 0.3 per cent. Three different Ostwald viscometers were used in this work and four samples of mixed skimmilk, two viscometers being used with each sample. The data were plotted and a smooth curve was drawn which most nearly fitted the data.

TABLE 1

The relative and absolute viscosity, density, and specific gravity of skimmilk and a 5 per cent lactose solution at various temperatures

TEMPERATURE	VISCOSITY IN CENTIPOISE			VISCOSITY RELATIVE TO WATER		DENSITY			SPECIFIC GRAVITY		
	Water*	Skimmilk	5 per cent lactose solution	Skimmilk	5 per cent lactose solution	Skimmilk		5 per cent lactose solution	Skimmilk		5 per cent lactose solution
						Experiment 1	Experiment 2		Experiment 1	Experiment 2	
°C.											
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
5	1.519	2.96	1.76	1.95	1.16	1.0369	1.0362	1.0204	1.0369	1.0362	1.0204
10	1.308	2.47	1.50	1.89	1.15	1.0360	1.0358	1.0200	1.0363	1.0361	1.0202
15	1.140	2.10		1.84		1.0348	1.0348		1.0357	1.0358	
20	1.005	1.79	1.15	1.78	1.14	1.0338	1.0338	1.0182	1.0356	1.0356	1.0200
25	0.894	1.54	1.03	1.72	1.15	1.0323	1.0321	1.0165	1.0353	1.0352	1.0198
30	0.801	1.33	0.91	1.66	1.14	1.0305	1.0307	1.0155	1.0350	1.0352	1.0199
35	0.723	1.17		1.62		1.0287	1.0288		1.0348	1.0350	
40	0.656	1.04	0.74	1.58	1.13	1.0264	1.0268	1.0119	1.0344	1.0348	1.0198
45	0.599	0.93		1.55		1.0245			1.0346		
50	0.549	0.85	0.62	1.54	1.13	1.0223	1.0223	1.0075	1.0346	1.0346	1.0196
55	0.506	0.77		1.53		1.0198			1.0346		
60	0.469	0.71	0.52	1.52	1.11	1.0171	1.0172	1.0028	1.0344	1.0345	1.0199
65	0.436	0.66		1.52		1.0145			1.0346		
70	0.406	0.62	0.45	1.52	1.11	1.0117	1.0117	0.9972	1.0347	1.0347	1.0199
75	0.380	0.59		1.54							
80	0.357	0.57	0.39	1.59	1.09	1.0052	1.0055	0.9913	1.0343	1.0347	1.0200

* Bingham and Jackson (13).

The values for the viscosity of milk at 5°C. intervals of temperatures were read from the curve and are given in table 1. The relative viscosity was obtained by dividing the true viscosity of milk by the viscosity of water. Thus the term relative viscosity is used in its true sense and not as relative times of flow as is sometimes the case.

The viscosity and density of skimmilk at various temperatures are shown graphically in figure 1. The viscosity of skimmilk decreases as the temperature is raised. The relative viscosity indicates that the viscosity of skimmilk decreases more rapidly than the viscosity of water up to 60°C. Between 60° and 70°C. the viscosity of skimmilk and water change with

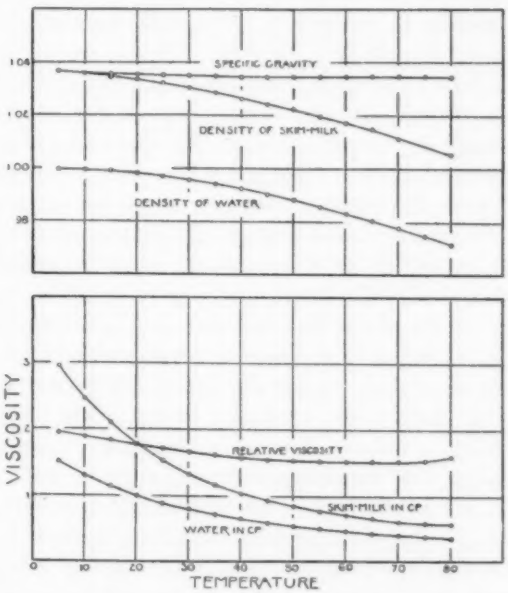

FIG. 1. THE DENSITY, SPECIFIC GRAVITY, ABSOLUTE VISCOSITY, AND RELATIVE VISCOSITY OF SKIMMILK AND WATER AT VARIOUS TEMPERATURES

temperature at the same rate, and above 70°C. the relative viscosity begins to rise again, indicating that the decrease in viscosity of skimmilk as the temperature is raised above 70°C. is not as rapid as the decrease in the viscosity of water. This break in the relative viscosity curve occurs at about the temperature at which heat denaturizes the albumin in milk. This point will be discussed later under the effect of pasteurization on viscosity.

The relative viscosity of skimmilk was found to be 1.95 at 5°C. and 1.52 at 60°C., or a change in relative viscosity of 0.43. Since the proteins and lactose are the main constituents of skimmilk, the question arises as to whether or not lactose would cause a change in the relative viscosity of milk as the temperature is raised. The viscosity of a 5 per cent solution of lactose at various temperatures is given in column 4, table 1, and the relative viscosity in column 6. The difference in relative viscosity between 5° and 60°C. is 0.04. This experiment indicates that the change in relative viscosity of skimmilk with temperature is due partially to the lactose, but that the effect of the lactose is small in comparison with the effect of the proteins.

It is probable, however, that the effect of both the lactose and the proteins on the relative viscosity is greater when taken together in the same solution than would be indicated by the sum of their individual effects when present alone in solution.

An examination of the density data given in table 1 shows that the density of the skimmilk also decreases more rapidly as the temperature is raised than does the density of water, this difference in rate of change practically all taking place below 40°C. Bowen's (14) data show a similar trend. The density data given in table 1, column 7, were obtained by starting at 5°C. and increasing the temperature in steps up to 80°C. It was feared that air might have been driven out of solution by the heat, and might have remained in the form of fine bubbles dispersed in the milk, which would account for the change. That this was not the case was shown by placing a sample of milk under the vacuum at 35° to 40°C. to remove the air, and then determining the densities in the reverse order starting with the highest temperature. The values obtained by this method are given in column 8, table 1. The total solids content of the skimmilk in experiment 2 was 8.96 per cent, the fat 0.07 per cent, and the proteins 3.22 per cent. The density data were changed to specific gravity, those obtained by increasing temperature are given in column 10; those by decreasing temperature in column 11. The specific gravity data indicate a change in hydration of the milk solids with temperature. This change in hydration

seems to be more marked as the temperature of the milk decreases from 40°C. The specific gravity of the skimmilk at 5°C. is 1.0366 and at 40°C. 1.0346, or a difference due to temperature of 0.0020. The density of a 5 per cent solution of lactose is given in column 9, table 1, and its specific gravity in column 12. These data indicate that the specific gravity of a 5 per cent solution of lactose changes 0.0005 between 5° and 40°C.

TABLE 2

Effect on the viscosity determined at 24°C. of pasteurizing skimmilk and rennet whey for thirty minutes at various temperatures

TEMPERATURE OF PASTEURIZATION	SKIMMILK		WHEY	
	Viscosity	Number of samples	Viscosity	Number of samples
°C.	cp.		cp.	
Unheated	1.472	62	1.158	9
50	1.434	9	1.146	2
60			1.159	2
62.5	1.440	13		
70	1.455	5	1.176	2
72.5	1.475	4	1.179	2
75	1.490	5		
77			1.193	3
78	1.515	3		
79	1.524	3		
80	1.527	8	1.208	2
82	1.540	3		
85	1.548	3		
90	1.553	4	1.294	2
100	1.603	4	1.381	3
110	1.647	3	1.296	3
120	1.717	3	1.273	4

Thus the lactose of the skimmilk is partly responsible for the change in specific gravity with temperature. Through the same range in temperature a 5 per cent sucrose solution changes 0.0006, which is about the same change as is produced by the lactose, while a 10 per cent sucrose solution changes 0.0013. Thus it is probable that the lactose has less effect on the change in specific gravity with temperature than has the protein material present in the skimmilk. The increase in specific gravity as the tem-

perature is lowered is not, however, sufficiently great to account for the distinct rise in the relative viscosity as the temperature is lowered.

The increase in the specific gravity and in the relative viscosity of skimmilk as the temperature is lowered both indicate that some change has taken place in the skimmilk. This change is probably a variation in the hydration of the milk constituents, probably the casein.

The effect of pasteurization on the viscosity of skimmilk and whey

The skimmilk or whey was pasteurized for thirty minutes at various temperatures, care being taken to prevent loss of moisture. It was then cooled at once to 24°C., held at this temperature for thirty minutes, and the viscosity determined with Ostwald viscometers at this temperature. In order to make the data obtained with the different samples of skimmilk comparable, they were converted to the percentage increase on the basis of the viscosity of the unheated sample, and then converted to the basis of the average viscosity for all of the unheated samples used. The data are given in table 2 and figure 2.

According to these data, pasteurization at temperatures between the normal temperature of the milk as drawn and about 72°C. causes a decrease in the viscosity of skimmilk, while pasteurization above this temperature, up to 120°C., causes an increase in viscosity. There is, however, a definite break in the curve, which occurs at about 83°C., the rate of change from this point on being somewhat less rapid.

The effect of pasteurization on the viscosity of rennet whey was also determined. The results are given in table 2 and figure 2. Pasteurization of whey causes a decrease in the viscosity between 40° and 60°C. From that point on as the temperature of pasteurization is raised, the viscosity increases at a slow rate up to about 75°C., and then at a much faster rate up to 100°C., and above this temperature the viscosity decreases again. The breaks in the whey and the skimmilk curves do not correspond. At the point where the skimmilk changes over to a slower rate, 83°C., the viscosity of the whey has just begun to increase at a

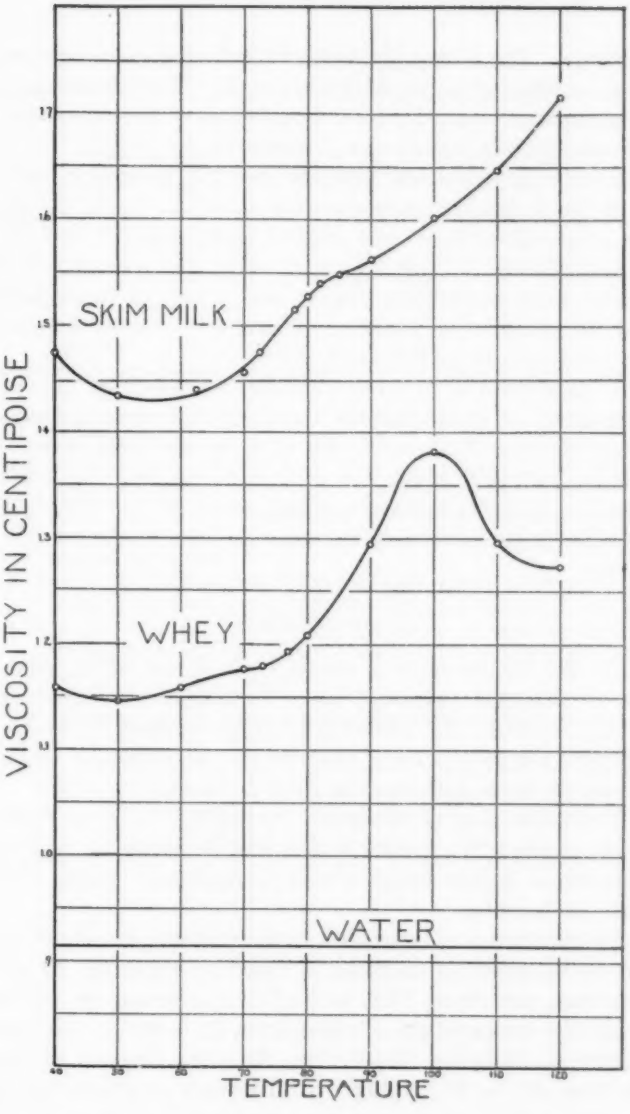

FIG. 2. THE VISCOSITY OF SKIMMILK AND WHEY AT 24°C. AFTER PASTEURIZING FOR 30 MINUTES AT VARIOUS TEMPERATURES

faster rate. The downward break in the whey curve apparently has no counterpart in the skimmilk curve. These results indicate the aggregates formed by heat coagulation of the whey proteins are markedly affected by the presence of the casein.

The data presented here indicate that the decrease in viscosity of milk due to holding pasteurization cannot be due to the coagulation of the albumin for two reasons, first, coagulation of the albumin would tend to increase the viscosity and, second, the maximum decrease in viscosity due to heat occurs at a temperature below the coagulation point of albumin, or where the rate of coagulation would be extremely slow.

The data for the relative viscosity of skimmilk at various temperatures as given in table 1 and figure 1 show a minimum between 60° and 70°C., while the data for the effect of pasteurization on viscosity where the milk is cooled and the viscosity determined at 24°C. indicate a minimum at 50° to 60°C. These minimum ranges are nearly the same as determined by the two methods.

CONCLUSIONS

1. As the temperature is raised from 5° to 60°C., the viscosity of skimmilk decreases faster than the viscosity of water; from 60° to 70°C. the viscosity of both decrease at about the same rate; and above 70°C. the viscosity of skimmilk decreases more slowly than does the viscosity of water.

2. Pasteurization of skimmilk for thirty minutes between 40° and about 72°C. causes a decrease in viscosity, while pasteurization at higher temperatures for the same length of time causes an increase.

3. Pasteurization of whey for thirty minutes at temperatures below 60°C. caused a decrease in viscosity, from 60° to 100°C. an increase, and from 100° to 120°C. a decrease in viscosity.

4. As the temperature is raised from 5° to 40°C. the density of skimmilk decreases faster than does the density of water, while from 40° to 80°C. they both decrease at about the same rate.

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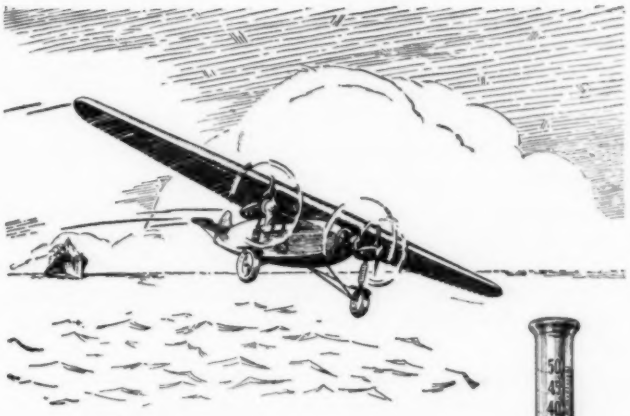

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